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# Constant Tension Wire Let-Off

Jeff Wilder

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**Indiana University – Purdue University Fort Wayne  
Department of Engineering**



**ME 487 –ME 488  
Capstone Senior Design Project  
*Report #2***

**Project Title:** Constant Tension Wire Let-Off

**Sponsor:** Fort Wayne Metals

**Team Members:** Jeff Wilder  
Cory Trischler  
Daniel Pucher

**Faculty Advisor:** Dr. Bongsu Kang

**Date:** May 5, 2010



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## **Abstract**

Fort Wayne Metals is a manufacturer of wire that can consist of multiple types of alloys used in the medical industry. As the medical field grows, as do their customer requirements and specifications needed to produce their products. The wire manufacturing process has an infinite number of variables that can affect the outcome of the final product from annealing temperatures to drawing speeds. The goal of the engineering staff at Fort Wayne Metals is to reduce the variation in their products and also use the variables to manipulate the mechanical and chemical properties of the wire as the customer desires.

Our Senior Design Team was tasked with improving their strand annealing process variation. They found that their current Let-Off design was causing a tension fluctuation within their approximately 1200°C furnace which can further cause diameter variation at this elevated temperature. The tension variation can also cause the wire to sag across the furnace span, low enough to contact the containment tubes and scratch the wire. If the wire is scratched at this point in time, further drawing of the scratched wire can yield pitted and cracked wire at the smaller sizes, which thereby can cause rejection of the material and losses.

Upon testing the team found that the currently used Let-Off allows the wire to increase in tension as the spools unwind. This increase in tension was found to be the cause of the magnetic brake not changing its resisting torque as the wire gets closer to the core of the spool. In order for the wire to continue moving, the tension the wire is observing must increase in order to compensate for the shorter torque arm during rotation. With further observation, it was found that during operation the wire tension would fluctuate wildly as the wire “snapped” off of the other winds of wire on the spool. This “snapping” is mainly caused by the uneven winding from previous processes both from Fort Wayne Metals supplier and their own drawing machines and the high tension involved in the annealing process.

The Senior Design Team wanted to attack the tension fluctuation from both fronts with their own design and compensate for both the changing resisting torque and reduce the “snapping”. The first concept was implementing a magnetic brake that would adjust its resisting torque as the spool unwinds and the wire gets closer to the spool core. The second concept is the addition of a pulley/cylinder that will induce a lateral friction parallel to the rotational axis of the spool that will make sure the wire is pulled off the spool at a 90° angle to reduce the “snapping” across the peaks and valleys.

The design was fabricated and calibrated at Fort Wayne Metals and tested according to parameters and requirements set at the beginning of the design process. The design performed very well under all sizes of wire required and has shown a 30-45% reduction in the vibration amplitude and all tensions were within our set windows. Upon further evaluation, the design did not meet two requirements as the small wire (0.0453” diameter) vibration amplitude was still slightly above our requirement and our maximum tension for the large wire (0.1020”) ended up stretching the wire by 0.0002” over specification.

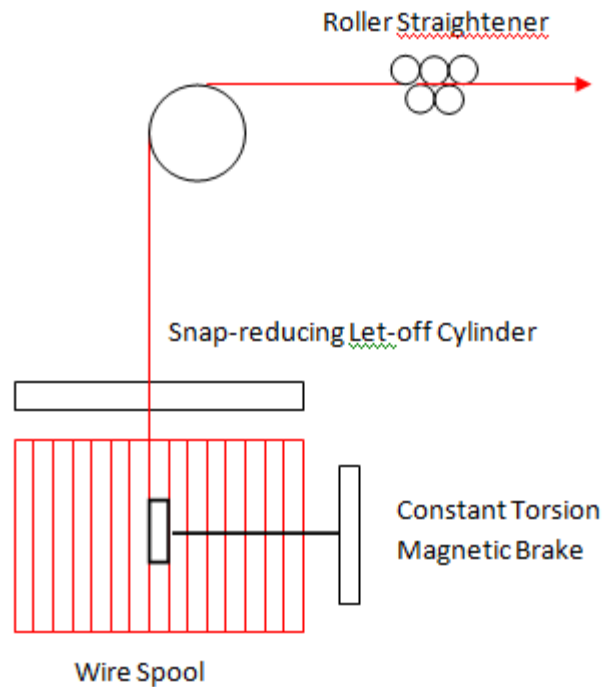
All parts of our design were regarded as safe and easy to use with a few additions and recommendations that would be advisable to perform at a later date by the engineers at Fort Wayne Metals as further tests can be performed and observations made. Overall the design was

a success and a vast improvement in the direction of reducing variation in their products and thereby increasing customer satisfaction later on the manufacturing process.



## **Section 1: Detailed Description of Final Conceptual Design**

## Section 1.1. Final Chosen Conceptual Design



**Figure 1:** Final Design Concept, Including a Constant Tension Magnetic Brake

Our final chosen conceptual design incorporates a snap-reducing cylindrical damper and a self-regulating magnetic braking system. The design must be able to keep the two test sizes of wire within their acceptable ranges of tension in order to perform correctly. The small size of wire (0.0453") can only withstand 5.173 lbf before it will deform in the furnace and must be kept above 3.167 lbf because if allowed to go below that tension the wire will contact the inner surface of the tube and cause surface damage. The large size wire (0.1020") can only withstand 26.226 lbf before it will deform in the furnace and must be kept above 17.583 lbf because the wire will contact the inner surface of the furnace tube and will cause surface damage. The ranges stated will be used extensively in the design process. Note that the tension ranges for the wires that are being used with the prototype have been changed since last semester due to further testing. This will be discussed in detail in the Section 4 of this report.

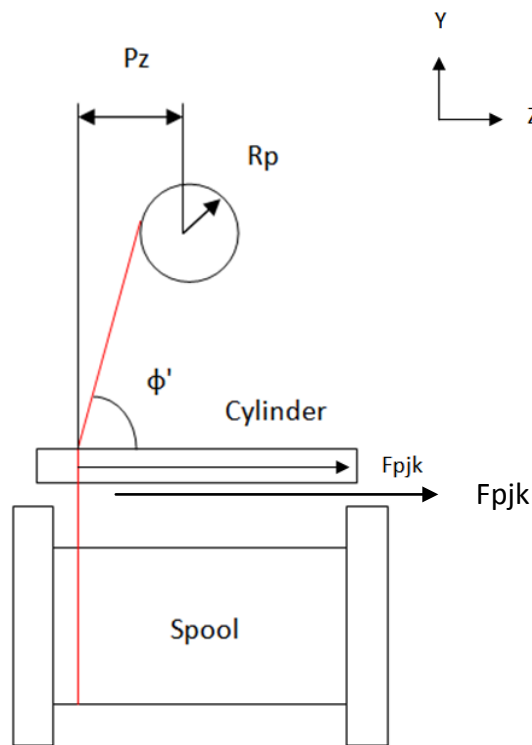
## **Final Design Components**

The following is our detailed analysis of each component of the final design concept.

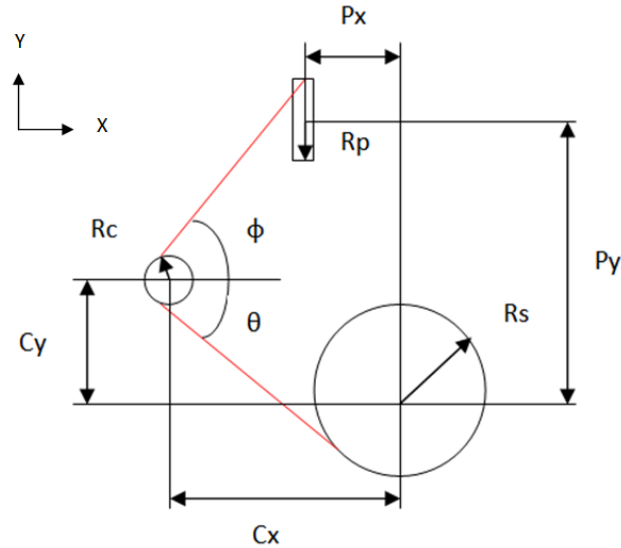
### **Section 1.2. Snap-Reducing Cylinder**

The snap-reducing cylinder implemented in the design will be used to place friction on the wire as it is pulled off of the spool, parallel to its axis of rotation, in order to force the wire to be pulled off of the spool tangentially. This will dampen the effect of the wire snapping off of the peaks and valleys of the wire wraps, which are caused by the wire being pulled off of the spool at varying angles. The height-adjusting pulley is required to be adjustable according to different heights of furnaces. This requirement is 36"-60" measured vertically from the ground. The placement of the snap-reducing cylinder is paramount in guaranteeing that a minimum normal force will be exerted on the cylinder from tension to exhibit the correct frictional axial force.

The figures below show a visual representation of the system that will be used:



**Figure 2:** The Cylinder-Spool System in the Z-Y Plane

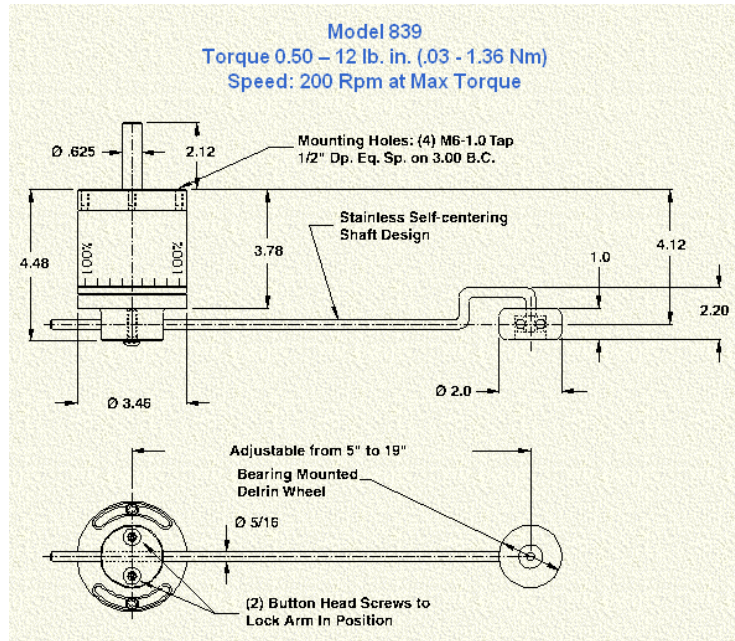


**Figure 3:** The Cylinder-Spool System in the X-Y Plane, where  $R_c$ ,  $R_p$ , and  $R_s$  are the radius of the cylinder, pulley, and spool, respectively

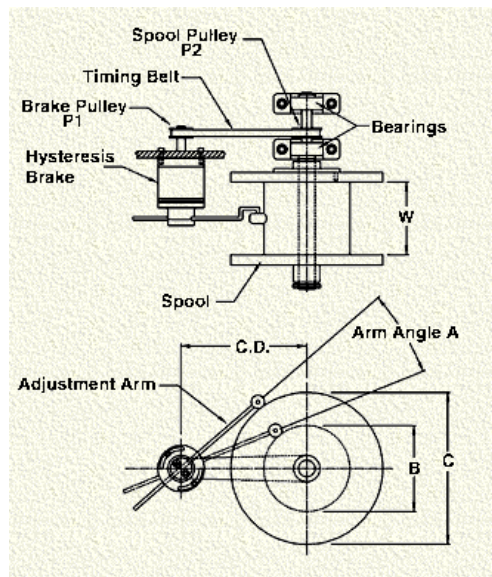
In order for the snap-reducing cylinder design to work, the frictional force must be greater than the axial force. This is because the wire should come straight up off of the spool without the wire slipping on the snap-reducing cylinder. We chose the center of the snap-reducing cylinder to be 2 feet back in the X direction from the center of the spool. This distance must be enough to allow clearance due to the radius of the spool and the radius of the cylinder. We also chose the snap-reducing cylinder to be 0.25 feet up in the Y direction. This position, combined with a minimum of a 0.1 frictional coefficient provided by a Delrin material, will allow the wire to be pulled off tangentially from the spool without slipping on the frictional cylinder.

### **Section 1.3. Self-Regulating Magnetic Brake**

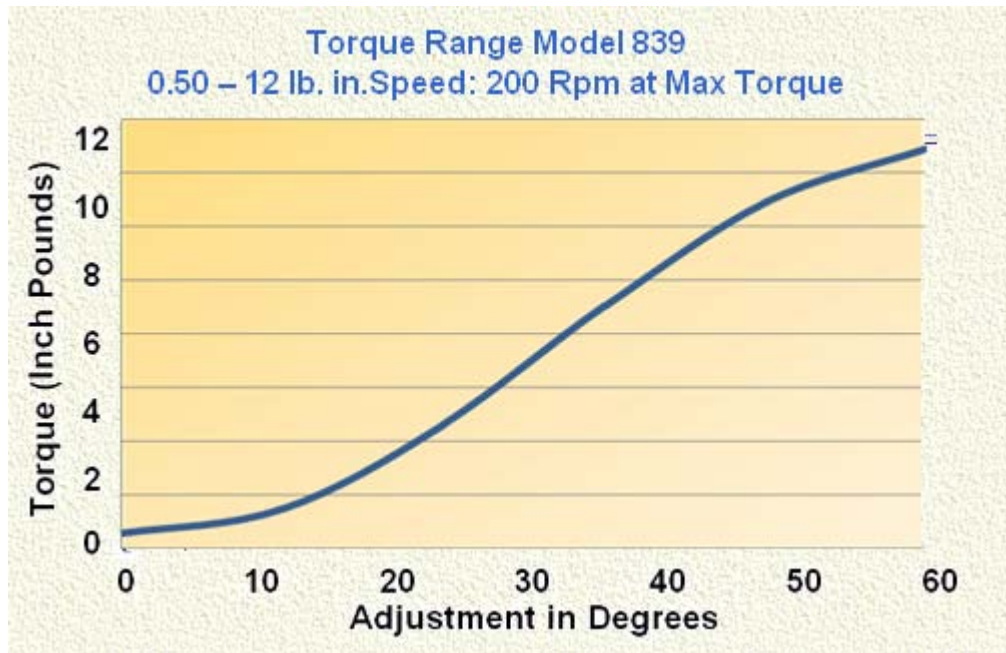
The self regulating magnetic brake will be implemented in our design to adjust the input torque to compensate for the increase in tension due to the “torque arm” changing as the spool empties. The spool will change its radius from 10” (full) to 7” (empty) during the life of the spool as it is fed to the annealing furnace. In order to keep the wire tension within an allowable tension variation of approximately 1 lbf, from our small wire analysis, this addition is required.



**Figure 4:** Magnetic Tech Model 1005 Self-Adjusting Brake



**Figure 5:** Example of the Self-Adjusting Brake Connected to a Spool



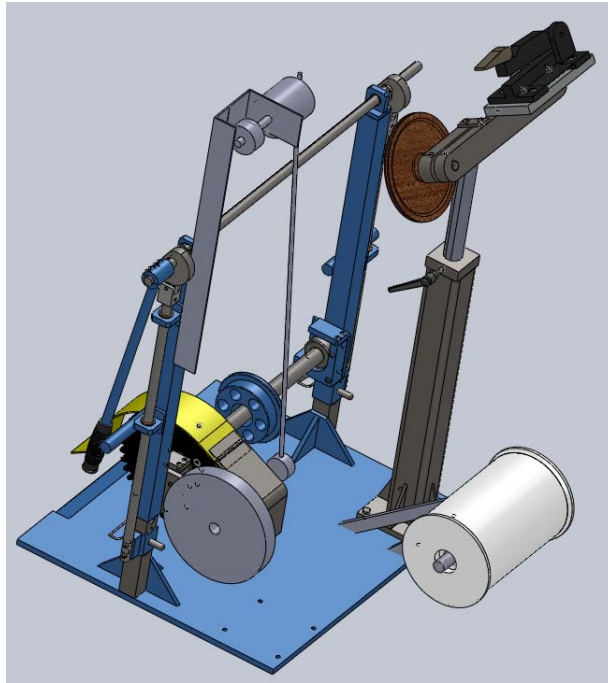
**Figure 6:** Torque (in-lb) Plotted against the Adjustment in Degrees of the Model 839 Brake

The torque induced by the small wire starts at 46.93 in-lb and as the spool is fed will decline to 32.851 in-lb and in order to compensate for this the magnetic brake must decrease the same amount of torque.

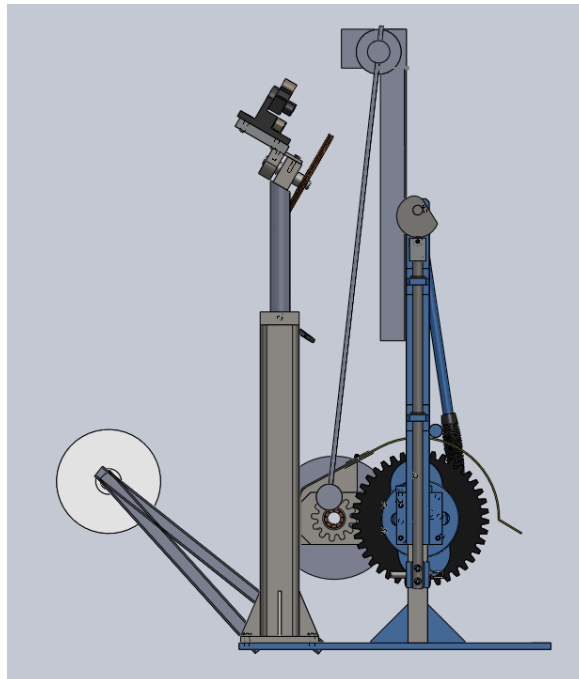
The length of the magnetic brake arm can theoretically be adjusted according to the wire size, but this has been avoided to simplify the set up process used by the operators. If the arm length is not to be changed, then the arm must be built to accommodate the small size of wire (0.0453") because of the extremely tight required tension range. If the brake is accommodating the small wire size, then the same length must be checked for the large wire (0.1020") to make sure that the wire is not exceeding the desired tension. This is accomplished by using the same degrees of change in the magnetic brake (5°) and calculating to see if the under compensation of torque will push it over the deformation tension. A 7:1 gear ratio will be used to modify the braking system to meet the previously stated wire tension ranges. Note that this gear ratio is not the same ratio as stated during our previous semester of senior design. This change will be discussed in detail in Section 4 of this report.

## **Section 1.4. Frame and Brackets**

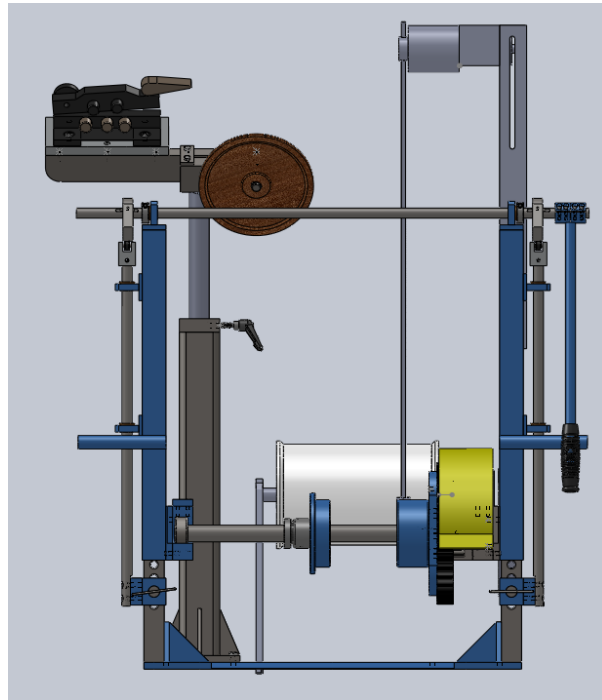
We will manufacture our own brackets to attach our snap-reducing cylinder and self-adjusting brake to the standard frame. The following figures show the brackets that we will be using:



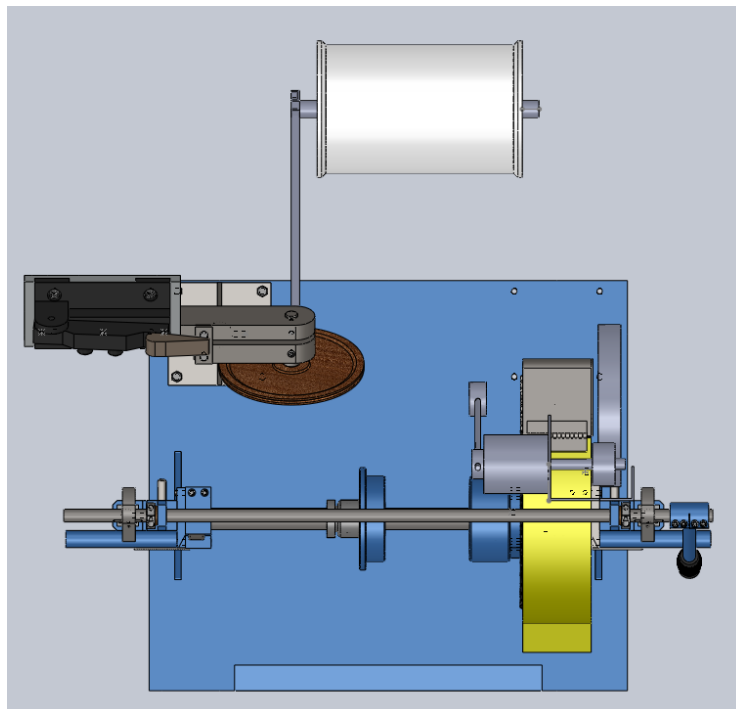
**Figure 7:** Overview of frame and additions



**Figure 8:** Side view of frame and additions

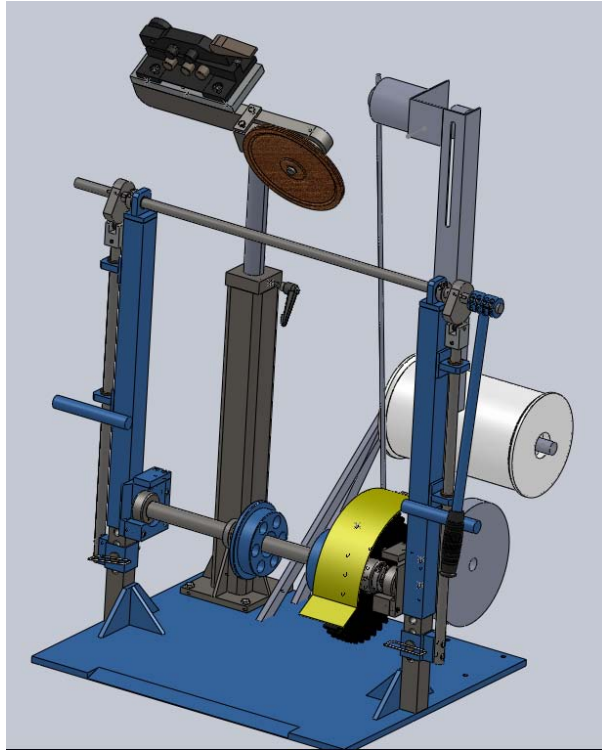


**Figure 9:** Side view of frame and additions

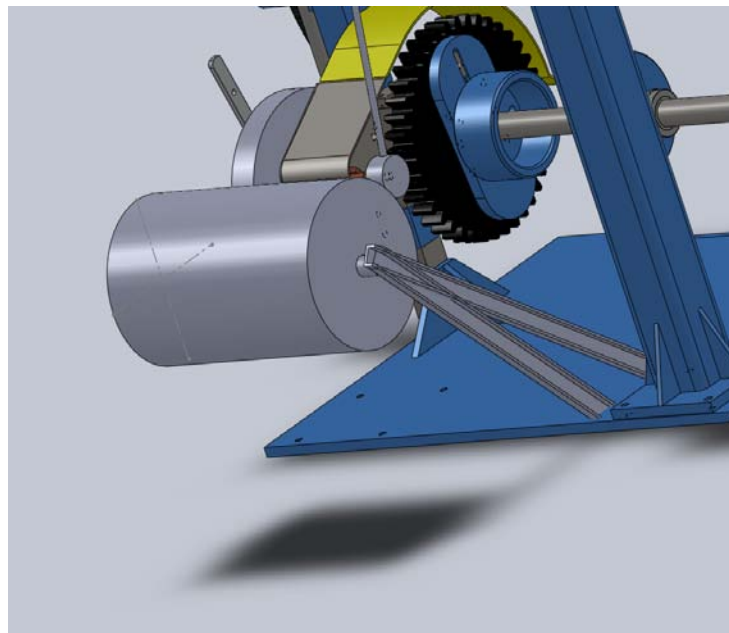


**Figure 10:** Top view of frame and additions





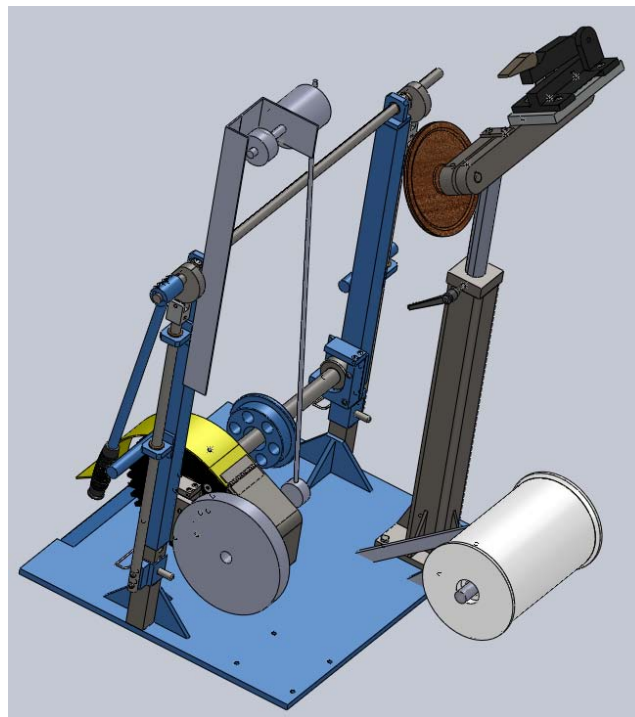
**Figure 11:** Overview of belt pulleys on magnetic brake



**Figure 12:** Snap-Reducing Cylinder attachment Bracket.



**Figure 13:** Self-Adjusting Brake attachment Bracket.



**Figure 14:** Final Design Frame Assembly.

### **Section 1.5. Cost Analysis**

The final design will consist of the standard Fort Wayne Metals frame including the parts and labor, a Magnetic Tech Model 1005 brake, three Phenolic pulleys, a Delrin snap-reducing cylinder, and a roller straightener. Fort Wayne Metals provided us with a cost estimate for the machining and labor to construct a standard frame for our design as well as the price for the Phenolic pulleys, the roller straightener, the Delrin snap-reducing cylinder, and the labor required to machine any other parts required. Most of the parts that are needed for the frame are bought from McMaster-Carr, and a full list of the individual parts for the frame is included in the appendix of this report. We acquired a price estimate on the self-adjusting brake from the Magnetic Tech Company. The following list is the compilation of our price estimates for the various components of our final design:

Magnetic Tech Model 1005 Brake - \$990

3 x Phenolic Pulleys - \$90

Delrin Snap-Reducing Cylinder - \$200

Roller Straightener - \$980

Standard Fort Wayne Metals Frame - \$1340, see appendix for list of individual parts.

Machined Parts and Labor - \$2850

These estimates give our final design a total estimated cost of \$6,450.

## **Section 2: The Prototype Building Process**

## **Section 2.1. Original Let-Off (Starting Point)**

Our prototype was created by retrofitting our improvements to an originally designed “let-off” device. Our improvements included a “snap reducing cylinder” attachment and a redesign of the braking system that is self adjusting according to how much wire is on the spool during the entire length of the annealing process. These two additions are the heart of our design project.

The start of the fabrication process involved having Fort Wayne Metals order and fabricate an original “let-off” as if they were to just buy another original “let-off” and allowed us to make changes to it (Figure 15). Fort Wayne Metals ordered the basic parts and had a separate company machine the original needed custom parts to assemble the original “let-off”. Once parts were on hand the original let-off was assembled by Jeff Wilder using hand tools and then function tested for clearances and machining errors.

Note: Solidworks files are to be used for reference only when building a second generation set. The understanding of the program was minimal at best and some parts are not as fabricated.

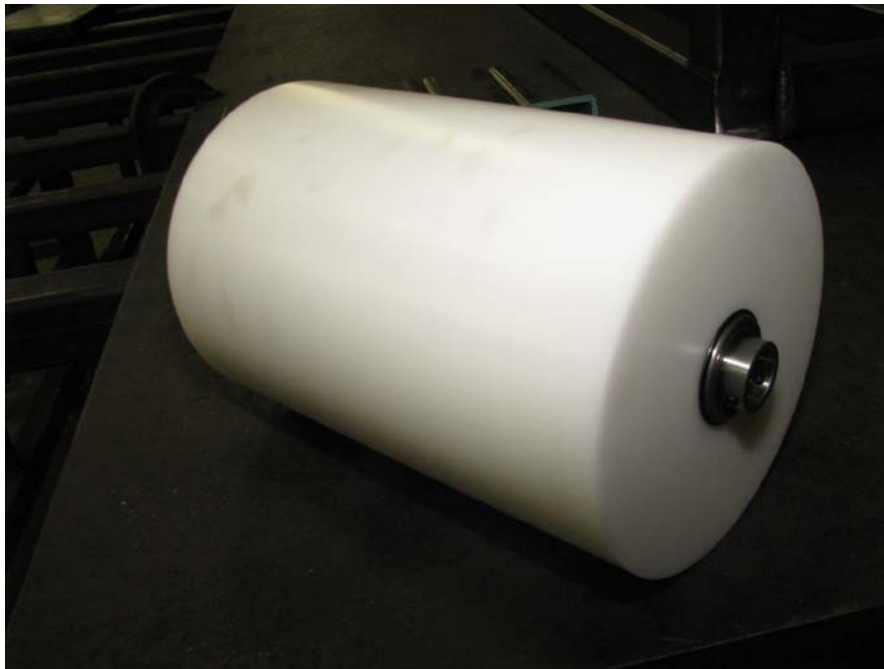


**Figure 15:** Original Let-off Design and Basis for our Design

## **Section 2.2. Snap Reducing Cylinder**

The first addition to the let off was the snap reducing cylinder at the rear of the let-off. The snap reducing cylinder was created by starting out with a 8" diameter by 12" long solid cylinder of Acetal Copolymer (McMaster part number 8497K651) and turning it on a lathe to the dimensions shown in Figure 16 with further additions after testing of chamfers at the ends. Once the cylinder was turned down and the internal surfaces were turned down then two bearings (McMaster part number 4768K7) as shown in Figure 17 were then press fitted into each side of the cylinder.

The frame that supports the snap reducing cylinder was then created. A 1" solid steel shaft was cut to length according to designs. The U-brackets originally decided upon in Semester 1 were not readily accessible and so some 1"x 2" square tubing was substituted and welded together at the appropriate angles side by side (Figure 18,19). The square tubing A-frame was then welded to the steel base at the appropriate placement and the previously cut shaft was then welded to the top intersection of the A-frame. Once the supporting frame had cooled the cylinder with press fitted bearings were slid onto the 1" shaft and secured to the shaft using the supplied bearing set screws to prevent shifting of the cylinder horizontally. We later added a lip to the outer edges of the cylinder as the larger wire's more aggressive cast cause the wire to wander off of the cylinder during operation (Figure 21).



**Figure 16:** Front View of Snap Reducing Cylinder





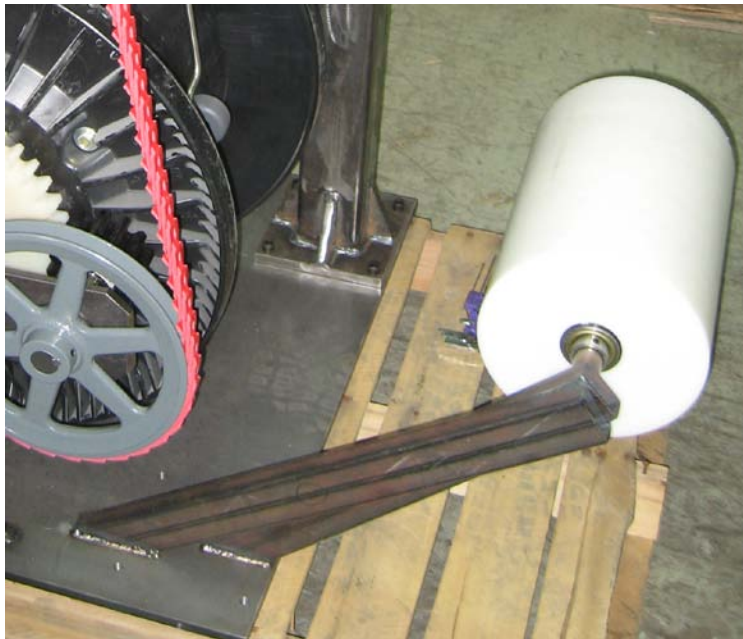
**Figure 17:** Side View of Snap Reducing Cylinder



**Figure 18:** Parts for Snap Reducing Cylinder A-frame



**Figure 19:** Second View of Cuts in Parts for Snap Reducing Cylinder A-frame



**Figure 20:** Welded and Assembled A-frame, Shaft and Cylinder

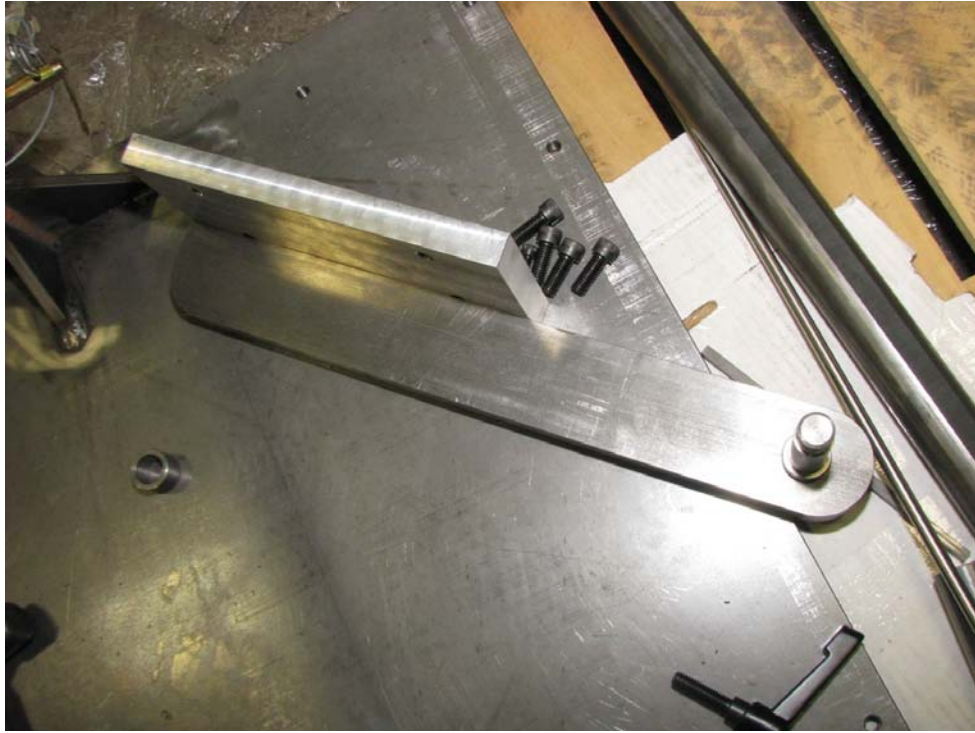




**Figure 21: Snap-Reducing Cylinder with added Lip**

### **Section 2.3. Roller Straightener and Assembly**

The roller straightener itself was fabricated by a separate company and made to bolt to the original designed let off equipment. The original let off had a short adjustable height shaft of 1" diameter and a short tube stand made of 2"x2" square tube steel. The original let-off did not allow for our 36" to 60" needed variation and a height upgrade was needed. The shaft was redesigned to be approximately 30" long and 1.5" in diameter, along with a 30° chamfer on the top of the shaft. The 30° chamfer at the top of the shaft was installed to allow for the wire to enter the large pulley at less of a harsh angle and prevent the wire from jumping out of the apparatus (Figure 24). The shaft was still not able to fully extend to the desired final height of 60" and so the 2" x 2" steel stand was extended 4" by welding on an additional section. The top of the stand also needed to be changed because the shaft diameter was now 0.5" larger and would not fit into the stand. The top of the stand was then carefully removed and machined to a new diameter of 1.503" and welded back onto the top of the stand.



**Figure 22:** Some Parts for Roller Straightener



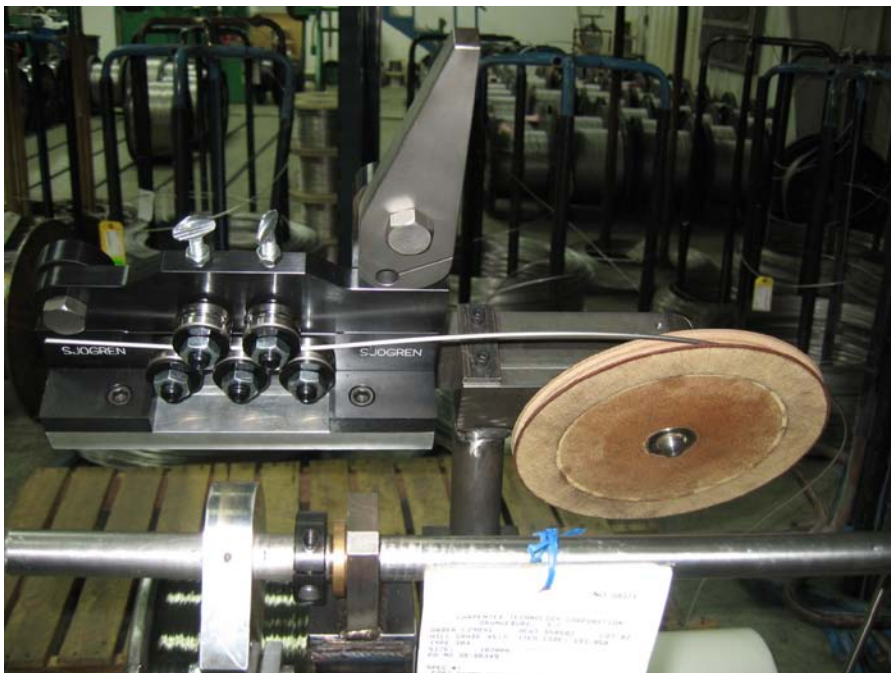
**Figure 23:** Assembled Parts for Roller Straightener and Final Pulley at Original Angle



**Figure 24:** Assembled Parts for Roller Straightener and Final Pulley at Final Angle of 30°



**Figure 25:** Assembled Roller Straightener



**Figure 26:** Assembled Roller Straightener

## **Section 2.4. Pulley System and Magnetic Brake**

The pulley and magnetic brake system was another important part of our design and needed special care in assembly. The first thing that came about was finding out that it would be very expensive and hard to find an adjustable length timing belt that we had originally decided upon for our design. We were able to find a nylon adjustable B-section V-belt (McMaster part number 6173K38) and two pulleys (Large pulley McMaster part number 6204K422 / Adjustable pulley McMaster part number 6205K142) that combined to obtain the final overall gear ratio of 7:1. We purchased our adjustable magnetic brake (Model 839-016) from Magnetic Technologies Ltd., based in Oxford, Massachusetts.

In attaching the magnetic brake to the let-off we used 2" x 2" angle iron with an elongated hole to allow adjustment of the brake height as needed (Figure 27). A second piece was fabricated for the brake to mount directly to the frame and still allow adjustment of height. The second main fabrication area needed was deciding how the gears were going to mesh together. The original let-off used the old magnetic brake as the bearing surface that the small gear attached to from the spool and we have completely removed the brake and so a bearing and new bracket was needed to be fabricated.

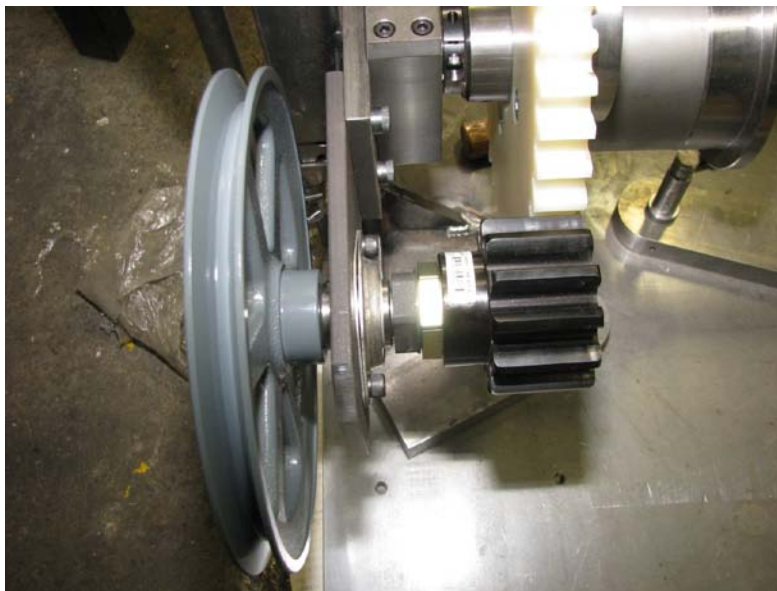
The new magnetic brake set up needed to mount a bearing to the frame directly and allow a 1" shaft to turn freely and be keyed to rotate with the large pulley and the small gear. A bearing was purchased (McMaster part number 2431K73) for its thin profile and ease of mounting to our system. A problem was found that the thin profile design allowed the bearing to float and rotate to align with a shaft and we did not want this rotation except around the shaft axis. Upon initial testing it was found that the clamping forces of the mounting system were not enough to counteract the floating action and was decided to spot weld the bearing cage to the bearing frame. This proved to work fine for now and is recommended to replace the bearing for further builds (Figure 29-31).

Originally we had purchased 2 other small pulleys and each one did not allow our wire tensions to stay within all windows for both sizes of wire and so it was decided to purchase an adjustable small pulley to allow fine adjustment as needed. The final calibration yielded the ration of 7:1 which was much lower than our 15:1 which we attributed to the frictional gains in tension that we could not have easily calculated (Figure 32-34).





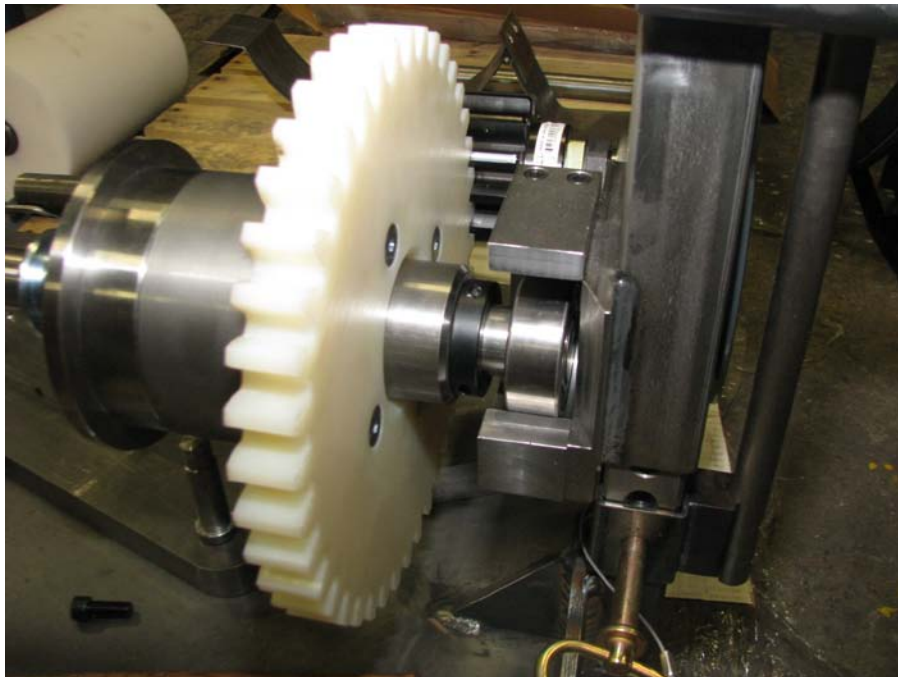
**Figure 27:** Picture of Magnetic Brake Frame



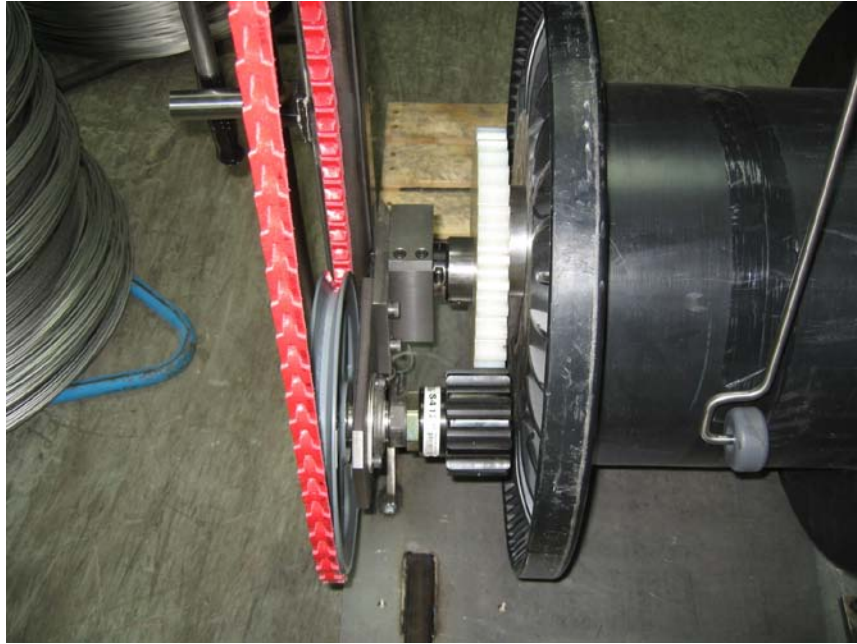
**Figure 28:** Picture of lower pulley and gear mesh



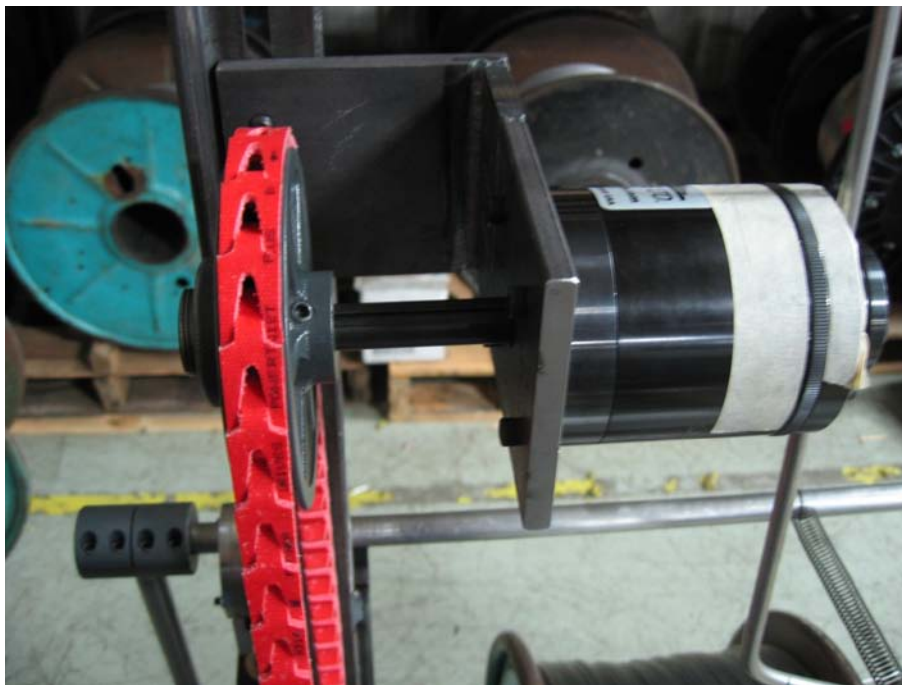
**Figure 29:** Picture of Lower Pulley and Gear Mesh with Spool Shaft



**Figure 30:** Picture of Lower Pulley and Gear Mesh from Front and Shaft Holder



**Figure 31:** Lower Portion of Pulley and Bearings



**Figure 32:** Upper Portion of Adjustable Pulley and Adjustable Magnetic Brake





**Figure 33:** Picture of Magnetic Brake and Calibration Marks



**Figure 34:** Picture of Magnetic Brake and Lever Arm Contacting Wire on Spool

## **Section 2.5. Safety Additions**

The pulleys attached to the gearing system and the gearing system itself poses a significant pinch risk to the operators of the machinery. A steel “safety” cover was then fabricated using sheet metal to cover all moving parts of the braking system. The sheet metal was cut and welded into a 5 sided box that allowed clearances for all internal moving parts and holes drilled to accommodate attachment screws. The framing for the magnetic brake was then drilled and tapped to accommodate the attachment screws. The hinged cover for the original “let-off” was then changed to allow for the new “safety box” and welded to the box to become one safety cover. The safety cover was created to be easily removed for maintenance and make sure an operator would not be able to get their fingers into the moving parts and cause an accident inadvertently (Figure 35). The final portion of the fabrication was just to paint the let-off to match the paint scheme of the rest of the let-off devices using “Filmtec Green” for the frame and yellow for the safety shielding (Figure 36-39).



**Figure 35:** Picture of Original Gear Cover used on Normal Let-Offs



**Figure 36:** Finished Safety Shield Eliminates Pinch Points



**Figure 37:** Final Prototype, Front



**Figure 38:** Final Prototype, Left



**Figure 39:** Final Prototype, Right

### **Section 3 – Testing the Prototype**

## **Design Requirements and Parameters**

### **Section 3.1. Wire Diameter Tolerance**

Because of tension differences and the temperature of the wire, when going through the annealing process, the wire can stretch causing the wire diameter to decrease. The newly designed system must be able to hold the wire exiting the system to a certain tolerance as to maintain mechanical properties. By testing the largest and smallest wire that will be used in this annealing process, all other wire diameters are validated as well. It is assumed that if the wire diameter stays the same, the mechanical properties are the same assuming the heating process is unchanged and the wire is moving at a constant velocity. The wire diameter variation should be no more than 0.001 inches after going through the annealing furnace using the redesigned let-off device. The process engineer has given us this target to meet, assuming that the change in mechanical properties of the wire will be negligible if this tolerance is held.

### **Section 3.2. Wire Oscillation**

Due to tension differences, the wire, while traveling through the annealing process, will oscillate. The wire, while at an elevated temperature, is susceptible to surface defects if it comes into contact with another object causing pitting and cracking which is undesirable to the manufacturing process. It is assumed that by testing the largest and smallest wire that will be used in this annealing process, all other wire diameters are validated as well. Also, the surface defects are only caused when the wire makes contact with an object while it is at the annealing temperature, going through the annealing process. The maximum wire diameter oscillation should be no more than 0.25 inches. When the wire enters the furnace tube, it is supported by a cork that holds the wire 75% of the entire 1 inch diameter tube relative to the bottom. This gives 0.25 inches (the worst case scenario) that the wire could oscillate before hitting the top of the furnace tube.

### **Section 3.3. Wire Feed Rate**

Feed rate refers to the velocity of the wire as it is traveling through the entire annealing process. The manufacturing plant uses certain feed rates to obtain certain mechanical properties of the wire. It is assumed that by testing the slowest and fastest wire feed rates that will be used in this annealing process, all other wire feed rates are validated as well. It is also assumed that the wire travels at a constant velocity throughout the entire annealing process. The redesigned wire let-off system should accommodate a wire velocity range of 4-30 feet per minute. These velocities are required to obtain the appropriate mechanical properties of the wire, based on the diameter of the wire.

### **Section 3.4. Wire Diameter**

Wire diameter refers to the ability of the redesigned let-off device to accommodate certain wire diameters. The manufacturing plant is required to produce several types of wire that vary in diameter. It is assumed that by testing the largest and smallest wire that will be used in this annealing process, all other wire diameters are validated as well. The redesigned wire let-off

system should accommodate a wire diameter minimum of 0.0453 and a maximum of 0.1020 inches.

### **Section 3.5. Wire Material**

Wire material refers to the ability of the redesigned let-off device to accommodate certain wire materials. The manufacturing plant is required to produce several types of wire that vary in material. If the redesigned let-off device accommodates 304V Stainless Steel, then it will accommodate all other materials that will possibly be used in the let-off device. The redesigned let-off device must not fail due to the material of the wire.

### **Section 3.6. Wire Tension**

Wire tension refers to tension window that was calculated for each of the small diameter (0.0453”) and the large diameter (0.1020”) wire. This tension window was defined by the minimum tension required to suspend the wire within the furnace tube without making contact and the maximum tension the wire can experience without any deformation, taking into account the temperature of the wire, for each of the small wire diameter and the large wire diameter. The wire should not come into contact with the furnace tubes because surface defects can be imposed on the wire. Also the wire should not stretch due to customer tolerances and strength requirements of the wire. If the wire stays within its tension window, for each respective wire diameter, the wire will be free of surface defects and will not be stretched. Tension windows are derived from a combination of calculations in the first semester’s final report and this semester’s testing.

### **Section 3.7. Let-off Ground Contact Width**

Let-off ground contact refers to the width of the let-off device that is actually making contact with the ground under normal operating conditions. Since it is possible for Fort Wayne Metals to produce several let-off devices and arrange them in the same fashion as they are today, the width of the let-off device must not exceed what it is currently. It is assumed that if the ground contact width is no larger than what it is today, then the same or similar manufacturing floor set-up can be obtained. The ground contact width of the let-off device must be no greater than 28 inches as that is the current let-off device ground contact width.

### **Section 3.8. Wire Height**

Let-off wire height refers to the height of the wire entering in the furnace tubes as measured from the production floor. There are different furnaces that may use this redesigned let-off device that will require different heights of wire. It is assumed that if the redesigned let-off device can meet the maximum wire height and the minimum wire height, then it can meet all wire heights in between. The redesigned let-off device must be able to accommodate a wire minimum height of 36 inches and a wire maximum height of 60 inches. There will be no furnace that will require less than 36 inches or more than 60 inches that will be used with the redesigned let-off device.

### **Section 3.9. Device Safety**

The safety of this device refers to the subjective scale of how likely a person is to get injured while using this device. Safety is always a top priority. If this device is as safe as or safer than the device that Fort Wayne Metals is currently using, then it is acceptable. The redesigned let-off device must be rated as a pass or fail as given by a person that has used the previous let-off device. It is assumed that the people that use the device will have the best judgment on how the device will be used and how safe/unsafe the device is.

### **Section 3.10. Device Cosmetic Consistency**

The device's cosmetic consistency consists of matching the color of the newly redesigned let-off device with the rest of the manufacturing plant. When giving tours of the plant, it is not desired that one section stick out among the others, it is desired that the entire plant look and operate as one system. This also includes making markings on the pulleys in a spiral shape so that from across the floor, it can be seen if the device is running or not. The redesigned let-off device must match the rest of the plant décor and each moving pulley must have a spiral shape painted on it so as to be able to tell if the device is running or not. The rest of the plant has a certain décor and the redesigned let-off device must match.

This test will require one to obtain approximately 10 feet of the 0.0453 inch diameter wire that has not gone through the annealing process. The diameter will be measured every 3 inches and the data recorded. The highest diameter of this data will be noted. Then the maximum value of the incoming wire diameter and the minimum diameter of the normally-obtained annealed wire will be compared. This test assumes that the 10 foot span of the incoming wire accurately represents the entire condition of the spool.

### **Section 3.11. Calibrating the Constant Tension Magnetic Brake**

Before performing tests, the group had to calibrate the magnetic brake. The goal of calibrating the constant-tension magnetic brake was to obtain minimum and maximum torque settings and to adjust, within this window, the starting point for the large and small diameter wires so each respective wire will remain within its tension window throughout the spool.

**Note: The tests, “0.0453” Tension Window – Lower Bound” and “0.1020” Tension Window – Lower Bound”, as described below, must be performed before calibrating the constant-tension magnetic brake.**

### **Section 3.12. Obtaining the Range of the Constant-Tension Magnetic Brake**

1. Place a full spool of the 0.0453” diameter wire on the re-designed let-off device and set it up so as to allow wire to be pulled.
2. Attach a tension scale to the outgoing wire.
3. Pull, with the tension scale, the wire so as to obtain the constant-velocity tension in the wire.
4. Rotate the constant-tension magnetic brake clockwise.



5. Repeat Step 3.
6. If the results are higher, rotate the magnetic brake counter-clockwise.
7. Repeat Step 3.
8. Continue Steps 6 and 7 until a minimum tension output is obtained and mark the magnetic brake “MIN” at this point.
9. Rotate the magnetic brake the opposite direction so as to obtain the maximum tension output of the magnetic brake and label this “MAX” on the magnetic brake.

### **Section 3.13. Calibrating the Magnetic Brake for the 0.0453” Diameter Wire**

1. Place a full spool of the 0.0453” diameter wire on the re-designed let-off device and set it up so as to allow wire to be pulled.
2. Starting with the minimum setting on the magnetic brake, pull the wire so as to obtain the constant-velocity tension in the wire. If this value is above the lower bound of the tension window for the 0.0453” diameter wire, change the pulley connected to the magnetic brake to a larger one. If this value is below the lower bound of the tension window for the 0.0453” diameter wire, rotate the magnetic brake towards the maximum a very small amount. Continue until the lower bound of the tension window for the 0.0453” diameter wire is met. Mark the magnetic brake “0.0453 Start”.
3. Place a near empty spool of 0.0453” diameter wire on the re-designed let-off device and set it up so as to allow the wire to be pulled.
4. Set the magnetic brake to the maximum setting and pull the wire so as to obtain the constant-velocity tension in the wire. If this value is greater than the upper bound of the tension window for the 0.0453” diameter wire, change the pulley connected to the magnetic brake to a larger one. If this value is less than the upper bound of the tension window for the 0.0453” diameter wire you are finished calibrating the 0.0453” diameter wire.

### **Section 3.14. Calibrating the Magnetic Brake for the 0.1020” Diameter Wire**

1. Place a full spool of the 0.1020” diameter wire on the re-designed let-off device and set it up so as to allow wire to be pulled.
2. Starting with the minimum setting on the magnetic brake, pull the wire so as to obtain the constant-velocity tension in the wire. If this value is above the lower bound of the tension window for the 0.1020” diameter wire, change the pulley connected to the magnetic brake to a larger one. If this value is below the lower bound of the tension window for the 0.1020” diameter wire, rotate the magnetic brake towards the maximum a very small amount. Continue until the lower bound of the tension window for the 0.1020” diameter wire is met. Mark the magnetic brake “0.1020 Start”.
3. Place a near empty spool of 0.1020” diameter wire on the re-designed let-off device and set it up so as to allow the wire to be pulled.
4. Set the magnetic brake to the maximum setting and pull the wire so as to obtain the constant-velocity tension in the wire. If this value is greater than the upper bound of the tension window for the 0.1020” diameter wire, change the pulley connected to the magnetic brake to a larger one. If this value is less than the upper bound of the tension

window for the 0.1020” diameter wire you are finished calibrating the 0.0453” diameter wire.

Several trials may be required to obtain a pulley, connected to the magnetic brake that will allow both wire’s tension windows to be attainable while running the spool in the annealing process.

## **Validation Plan and Results**

### **Section 3.15. 0.0453” Wire Diameter Variation**

The objective of this test is to determine if the wire diameter variation of the normally produced wire, using the re-designed let-off device, is less than or equal to 0.001 inches for the small diameter wire. The re-designed let-off will be ran so as to accumulate approximately 20 feet of annealed wire. This wire will then be removed from the process and the diameter measured every 3 inches and the data recorded. The lowest and highest diameter of this data will be noted. If this variation is less than or equal to 0.001 inches, the test will have met the objective. If the variation is more than 0.001 inches the test will not have met the objective. This test assumes that a variation of 0.001 inches in diameter will cause acceptable mechanical property variation throughout the entire manufacturing process. This assumption was given by the Process Engineer, Rick Neuhaus.

The following table depicts the data that was collected for this test:

**Table 1:** Table showing the normally produced annealed wire diameter with respect to distance for the small diameter wire

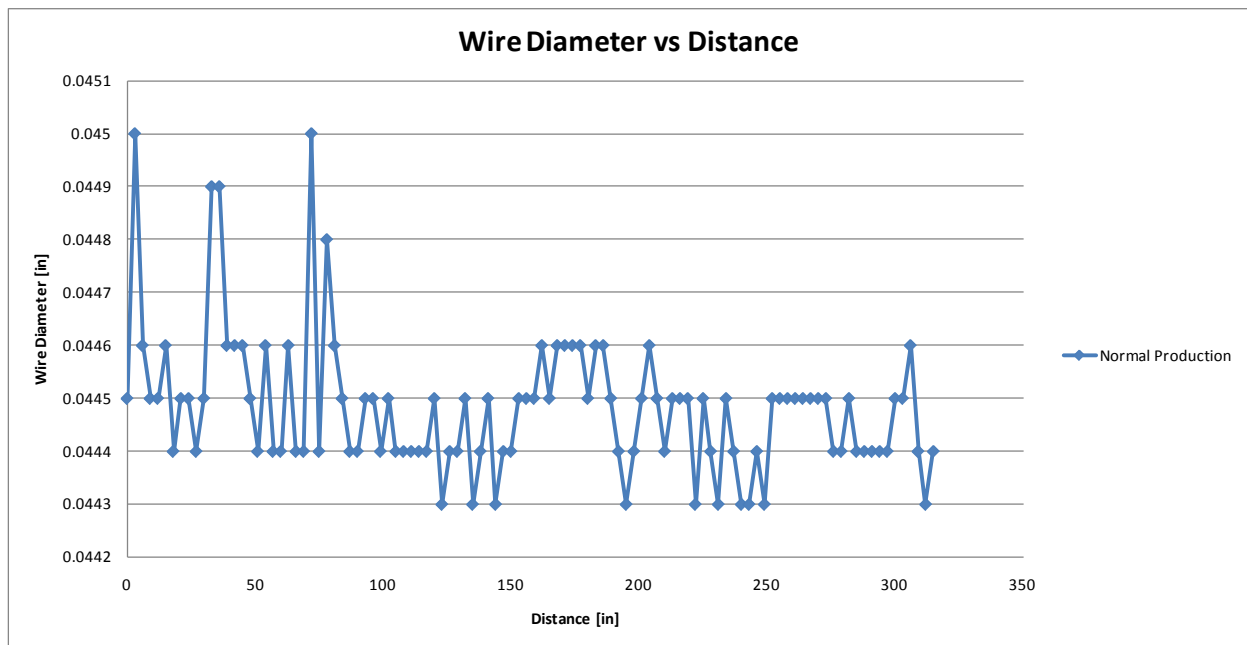
<b>Distance</b>	<b>0.0453 Normal Production</b>
0	0.0445
3	0.045
6	0.0446
9	0.0445
12	0.0445
15	0.0446
18	0.0444
21	0.0445
24	0.0445
27	0.0444
30	0.0445
33	0.0449
36	0.0449
39	0.0446
42	0.0446

45	0.0446
48	0.0445
51	0.0444
54	0.0446
57	0.0444
60	0.0444
63	0.0446
66	0.0444
69	0.0444
72	0.045
75	0.0444
78	0.0448
81	0.0446
84	0.0445
87	0.0444
90	0.0444
93	0.0445
96	0.0445
99	0.0444
102	0.0445
105	0.0444
108	0.0444
111	0.0444
114	0.0444
117	0.0444
120	0.0445
123	0.0443
126	0.0444
129	0.0444
132	0.0445
135	0.0443
138	0.0444
141	0.0445
144	0.0443
147	0.0444
150	0.0444
153	0.0445
156	0.0445
159	0.0445
162	0.0446
165	0.0445

168	0.0446
171	0.0446
174	0.0446
177	0.0446
180	0.0445
183	0.0446
186	0.0446
189	0.0445
192	0.0444
195	0.0443
198	0.0444
201	0.0445
204	0.0446
207	0.0445
210	0.0444
213	0.0445
216	0.0445
219	0.0445
222	0.0443
225	0.0445
228	0.0444
231	0.0443
234	0.0445
237	0.0444
240	0.0443
243	0.0443
246	0.0444
249	0.0443
252	0.0445
255	0.0445
258	0.0445
261	0.0445
264	0.0445
267	0.0445
270	0.0445
273	0.0445
276	0.0444
279	0.0444
282	0.0445
285	0.0444
288	0.0444

291	0.0444
294	0.0444
297	0.0444
300	0.0445
303	0.0445
306	0.0446
309	0.0444
312	0.0443
315	0.0444

The following figure represents, graphically, the data collected for this test:



**Figure 40:** Graph showing the wire diameter vs distance for the small diameter wire for the normally produced annealed wire

As it can be seen in Figure 40, the maximum diameter of the normal production wire for the 0.0453" diameter wire is 0.0450 inches. Also from Figure 40, the minimum diameter for the normal production wire is 0.0443 inches. Comparing these two numbers the maximum variation after going through annealing process by using our re-designed let-off device is 0.0007 inches. With a maximum variation of 0.0007 inches, the objective of this test has been met.

Although the diameter variation for the small diameter wire is less than 0.001 inches in this case, the incoming wire diameter variation has to be considered as having an effect on the annealed wire for the general case. While the let-off device plays a crucial role in the diameter variation in the process of annealing wire, the incoming wire diameter variation also plays a crucial role. If the incoming wire variation is too high, the let-off device will have little chance in keeping the

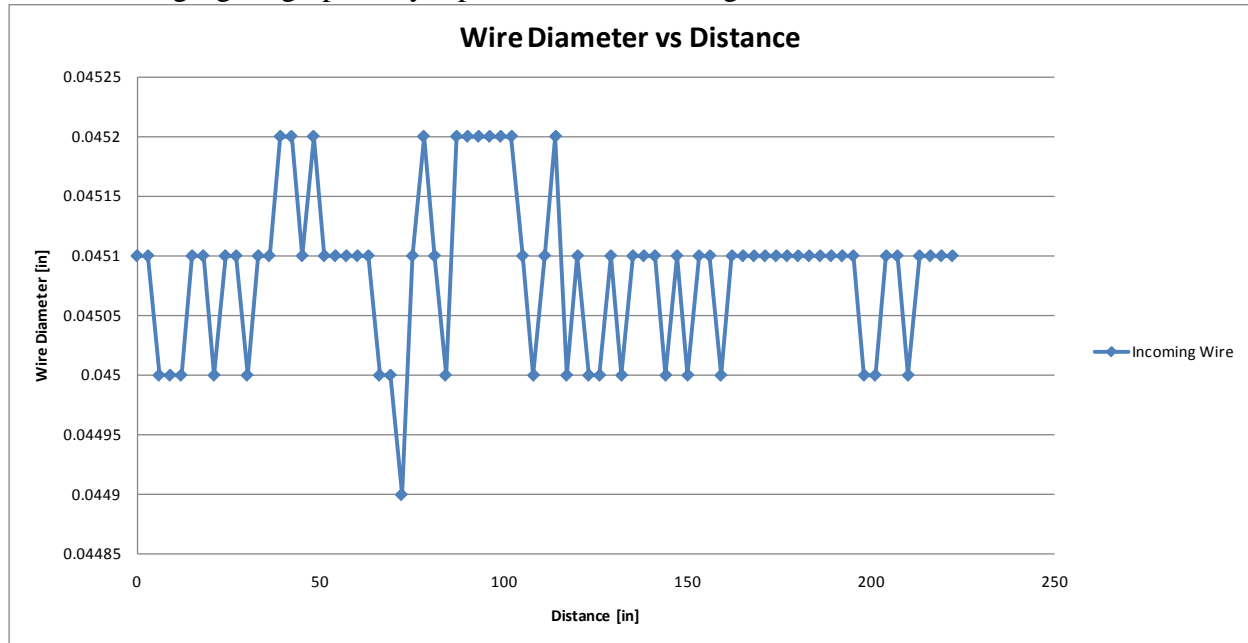
overall diameter variation to less than 0.001 inches. The following table shows the incoming wire diameter variation for the spool that was used in this test:

**Table 2:** Table showing the incoming wire diameter with respect to distance for the small diameter wire

<b>Distance (in)</b>	<b>0.0453 Incoming Wire (in)</b>
0	0.0451
3	0.0451
6	0.045
9	0.045
12	0.045
15	0.0451
18	0.0451
21	0.045
24	0.0451
27	0.0451
30	0.045
33	0.0451
36	0.0451
39	0.0452
42	0.0452
45	0.0451
48	0.0452
51	0.0451
54	0.0451
57	0.0451
60	0.0451
63	0.0451
66	0.045
69	0.045
72	0.0449
75	0.0451
78	0.0452
81	0.0451
84	0.045
87	0.0452
90	0.0452
93	0.0452
96	0.0452
99	0.0452

102	0.0452
105	0.0451
108	0.045
111	0.0451
114	0.0452
117	0.045
120	0.0451
123	0.045
126	0.045
129	0.0451
132	0.045
135	0.0451
138	0.0451
141	0.0451
144	0.045
147	0.0451
150	0.045
153	0.0451
156	0.0451
159	0.045
162	0.0451
165	0.0451
168	0.0451
171	0.0451
174	0.0451
177	0.0451
180	0.0451
183	0.0451
186	0.0451
189	0.0451
192	0.0451
195	0.0451
198	0.045
201	0.045
204	0.0451
207	0.0451
210	0.045
213	0.0451
216	0.0451
219	0.0451
222	0.0451

The following figure graphically represents the incoming wire diameter variation:



**Figure 41:** Graph showing the wire diameter vs distance for the small diameter wire for the incoming wire

As one can see, through the same method as above, the diameter variation for the incoming 0.0453" diameter wire is 0.0003 inches.

### **Section 3.16. 0.1020" Wire Diameter Variation**

The objective of this test is to determine if the wire diameter variation of the normally produced wire, using the re-designed let-off device, is less than or equal to 0.001 inches for the large diameter wire. The re-designed let-off will be ran so as to accumulate approximately 20 feet of annealed wire. This wire will then be removed from the process and the diameter measured every 3 inches and the data recorded. The lowest and highest diameter of this data will be noted. If this variation is less than or equal to 0.001 inches, the test will have met the objective. If the variation is more than 0.001 inches the test will not have met the objective. This test assumes that a variation of 0.001 inches in diameter will cause acceptable mechanical property variation throughout the entire manufacturing process. This assumption was given by the Process Engineer, Rick Neuhaus.



The following table depicts the data that was collected for this test:

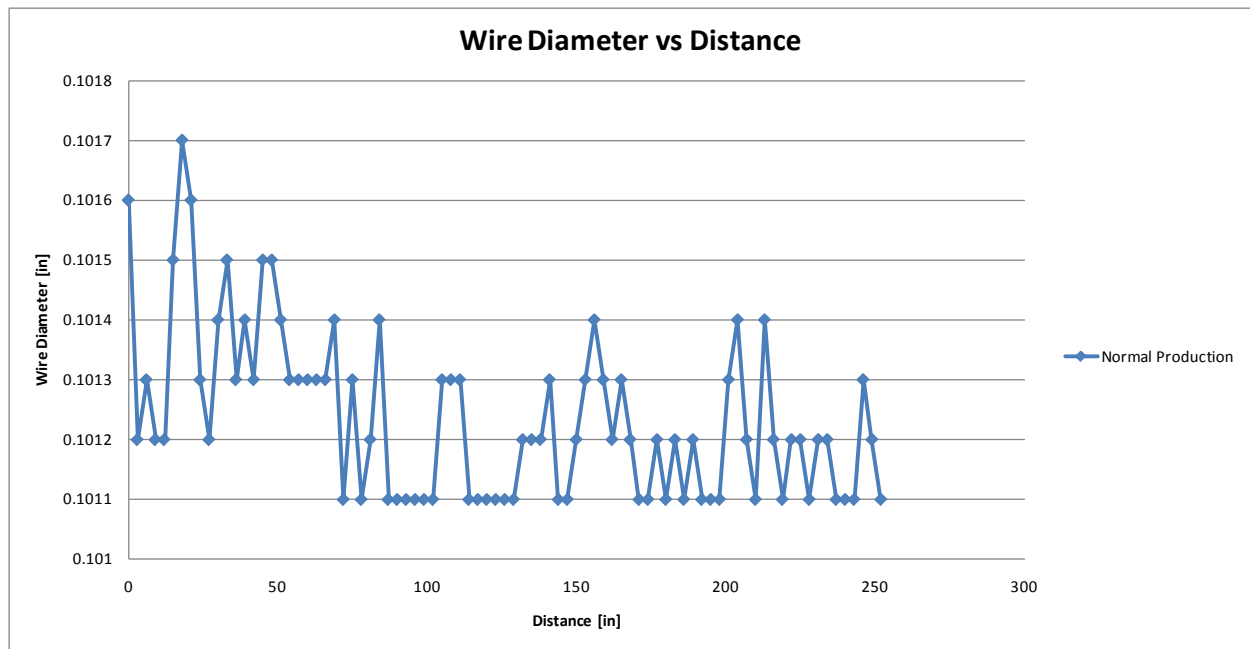
**Table 3:** Table showing the normally produced annealed wire diameter with respect to distance for the large diameter wire

<b>Distance</b>	<b>.102 Normal Production</b>
0	0.1016
3	0.1012
6	0.1013
9	0.1012
12	0.1012
15	0.1015
18	0.1017
21	0.1016
24	0.1013
27	0.1012
30	0.1014
33	0.1015
36	0.1013
39	0.1014
42	0.1013
45	0.1015
48	0.1015
51	0.1014
54	0.1013
57	0.1013
60	0.1013
63	0.1013
66	0.1013
69	0.1014
72	0.1011
75	0.1013
78	0.1011
81	0.1012
84	0.1014
87	0.1011
90	0.1011
93	0.1011
96	0.1011
99	0.1011
102	0.1011

105	0.1013
108	0.1013
111	0.1013
114	0.1011
117	0.1011
120	0.1011
123	0.1011
126	0.1011
129	0.1011
132	0.1012
135	0.1012
138	0.1012
141	0.1013
144	0.1011
147	0.1011
150	0.1012
153	0.1013
156	0.1014
159	0.1013
162	0.1012
165	0.1013
168	0.1012
171	0.1011
174	0.1011
177	0.1012
180	0.1011
183	0.1012
186	0.1011
189	0.1012
192	0.1011
195	0.1011
198	0.1011
201	0.1013
204	0.1014
207	0.1012
210	0.1011
213	0.1014
216	0.1012
219	0.1011
222	0.1012
225	0.1012

228	0.1011
231	0.1012
234	0.1012
237	0.1011
240	0.1011
243	0.1011
246	0.1013
249	0.1012
252	0.1011

The following figure graphically represents the incoming wire diameter variation:



**Figure 42:** Graph showing the wire diameter vs distance for the large diameter wire for the normally produced annealed wire

As it can be seen in Figure 42, the maximum diameter of the normal production wire for the 0.1020" diameter wire is 0.1017 inches. Also from Figure 42, the minimum diameter for the normal production wire is 0.1011 inches. Comparing these two numbers the maximum variation after going through annealing process by using our re-designed let-off device is 0.0006 inches. With a maximum variation of 0.0006 inches, the objective of this test has been met.

Although the diameter variation for the large diameter wire is less than 0.001 inches in this case, the incoming wire diameter variation has to be considered as having an effect on the annealed wire for the general case. While the let-off device plays a crucial role in the diameter variation in the process of annealing wire, the incoming wire diameter variation also plays a crucial role. If the incoming wire variation is too high, the let-off device will have little chance in keeping the

overall diameter variation to less than 0.001 inches. The following table shows the incoming wire diameter variation for the spool that was used in this test:

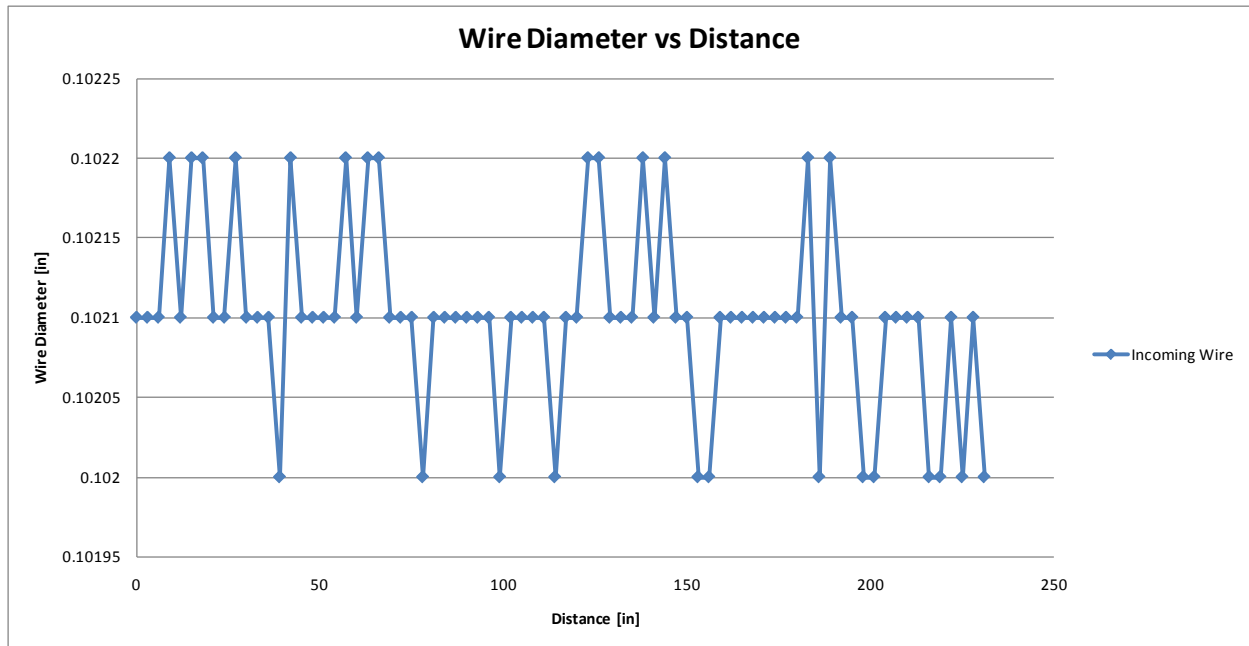
**Table 4:** Table showing the incoming wire diameter with respect to distance for the large diameter wire

<b>Distance (in)</b>	<b>.102 Incoming Wire (in)</b>
0	0.1023
3	0.1021
6	0.1021
9	0.1022
12	0.1021
15	0.1022
18	0.1022
21	0.1021
24	0.1021
27	0.1022
30	0.1021
33	0.1021
36	0.1021
39	0.102
42	0.1022
45	0.1021
48	0.1021
51	0.1021
54	0.1021
57	0.1022
60	0.1021
63	0.1022
66	0.1022
69	0.1021
72	0.1021
75	0.1021
78	0.102
81	0.1021
84	0.1021
87	0.1021
90	0.1021
93	0.1021
96	0.1021
99	0.102

102	0.1021
105	0.1021
108	0.1021
111	0.1021
114	0.102
117	0.1021
120	0.1021
123	0.1022
126	0.1022
129	0.1021
132	0.1021
135	0.1021
138	0.1022
141	0.1021
144	0.1022
147	0.1021
150	0.1021
153	0.102
156	0.102
159	0.1021
162	0.1021
165	0.1021
168	0.1021
171	0.1021
174	0.1021
177	0.1021
180	0.1021
183	0.1022
186	0.102
189	0.1022
192	0.1021
195	0.1021
198	0.102
201	0.102
204	0.1021
207	0.1021
210	0.1021
213	0.1021
216	0.102
219	0.102
222	0.1021

225	0.102
228	0.1021
231	0.102

The following figure graphically represents the incoming wire diameter variation:



**Figure 43:** Graph showing the wire diameter vs distance for the large diameter wire for the incoming wire

As one can see, through the same method as above, the diameter variation for the incoming 0.0453" diameter wire is 0.0002 inches.

### **Section 3.17. 0.0453" Wire Oscillation Amplitude**

The objective of this test is to determine if the wire oscillation for the 0.0453 inch diameter wire is less than or equal to 0.25 inches as measured in the center of a 17 foot span. For this test, an elevated ruler will be used to capture the amplitude of oscillation. In conjunction with the elevated ruler, two elevated corks will be required to support the wire so it is unobstructed for the entire 17 foot span. The test will be recorded for a duration of no less than 5 minutes. The video will then be reviewed so the maximum oscillation amplitude can be obtained. If this oscillation is less than or equal to 0.25 inches, the test will have met the objective. If the variation is more than 0.25 inches the test will not have met the objective. This test assumes that the set-up of an elevated ruler in the center of a supported 17 foot span wire accurately portrays the oscillation amplitude inside the furnace tube under normal operating temperatures and conditions.

After reviewing the recorded data, the maximum wire oscillation amplitude was 0.4375 inches for the small diameter wire. This was found by recording the minimum height throughout the test as well as the maximum height. These two values were subtracted to give us the total oscillation. This number was then divided by two to give the oscillation amplitude. Because this oscillation amplitude is greater than 0.25 inches, this test does not meet the objective.

### **Section 3.18. 0.1020" Wire Oscillation Amplitude**

The objective of this test is to determine if the wire oscillation for the 0.1020 inch diameter wire is less than or equal to 0.25 inches as measured in the center of a 17 foot span. For this test, an elevated ruler will be used to capture the amplitude of oscillation. In conjunction with the elevated ruler, two elevated corks will be required to support the wire so it is unobstructed for the entire 17 foot span. The test will be recorded for a duration of no less than 5 minutes. The video will then be reviewed so the maximum oscillation amplitude can be obtained. If this oscillation is less than or equal to 0.25 inches, the test will have met the objective. If the variation is more than 0.25 inches the test will not have met the objective. This test assumes that the set-up of an elevated ruler in the center of a supported 17 foot span wire accurately portrays the oscillation amplitude inside the furnace tube under normal operating temperatures and conditions.

After reviewing the recorded data, the maximum wire oscillation amplitude was 0.25 inches for the large diameter wire. This was found by recording the minimum height throughout the test as well as the maximum height. These two values were subtracted to give us the total oscillation. This number was then divided by two to give the oscillation amplitude. Because the oscillation amplitude is equal to 0.25 inches, this test does meet the objective.

### **Section 3.19. 0.0453" Wire Oscillation Amplitude – Old Let-off Device**

The objective of this test is to obtain the wire oscillation amplitude for the current let-off device for 0.0453 inch diameter wire as measured in the center of a 17 foot span. For this test, an elevated ruler will be used to capture the amplitude of oscillation. In conjunction with the elevated ruler, two elevated corks will be required to support the wire so it is unobstructed for the entire 17 foot span. The test will be recorded for a duration of no less than 5 minutes. The video will then be reviewed so the maximum oscillation amplitude can be obtained. If this maximum oscillation amplitude is obtained, the test will have met the objective. If the maximum oscillation amplitude is not obtained, the test will not have met the objective. This test assumes that the set-up of an elevated ruler in the center of a supported 17 foot span wire accurately portrays the oscillation amplitude inside the furnace tube under normal operating temperatures and conditions.

After reviewing the recorded data, the maximum wire oscillation amplitude was 0.75 inches for the small diameter wire. This was found by recording the minimum height throughout the test as well as the maximum height. These two values were subtracted to give us the total oscillation. This number was then divided by two to give the oscillation amplitude. Because this oscillation amplitude was obtained, the test's objective was met.



### **Section 3.20. 0.1020" Wire Oscillation Amplitude – Old Let-off Device**

The objective of this test is to obtain the wire oscillation amplitude for the current let-off device for 0.1020 inch diameter wire as measured in the center of a 17 foot span. For this test, an elevated ruler will be used to capture the amplitude of oscillation. In conjunction with the elevated ruler, two elevated corks will be required to support the wire so it is unobstructed for the entire 17 foot span. The test will be recorded for a duration of no less than 5 minutes. The video will then be reviewed so the maximum oscillation amplitude can be obtained. If this maximum oscillation amplitude is obtained, the test will have met the objective. If the maximum oscillation amplitude is not obtained, the test will not have met the objective. This test assumes that the set-up of an elevated ruler in the center of a supported 17 foot span wire accurately portrays the oscillation amplitude inside the furnace tube under normal operating temperatures and conditions.

After reviewing the recorded data, the maximum wire oscillation amplitude was 0.375 inches for the large diameter wire. This was found by recording the minimum height throughout the test as well as the maximum height. These two values were subtracted to give us the total oscillation. This number was then divided by two to give the oscillation amplitude. Because this oscillation amplitude was obtained, the test's objective was met.

### **Section 3.21. 0.0453" Tension Window – Lower Bound**

The objective of this test is to obtain the minimum tension that will prevent the wire from touching the furnace tube when going through the annealing furnace. In order for the wire not to touch the furnace tube, a deflection of 0.75 inches must be the maximum deflection of the wire when the wire is experiencing the least amount of tension. For this test, two identical pieces of wood that are at least one inch in height will be obtained along with 17 feet of fully annealed 0.0453 inch diameter wire. One end of the wire should be fixed to one of the pieces of wood. The other end of the wire should be attached to a tension scale to obtain a reading of tension applied to the wire while traveling over the second piece of wood. In the center of the span a ruler should be present to read the maximum deflection of the wire. The wire will then be pulled to a deflection of 0.5 inches, 0.75 inches, and 1 inch while making sure the wire ends stay parallel to the ground. If the minimum tension is obtained, the test will have met the objective. If the minimum tension is not obtained, the test will not have met the objective. This test assumes that the set-up of the fully annealed wire will behave in the same fashion as it would inside a furnace tube while hot.

**Table 5:** Table showing the required tension to elevate the small diameter wire at the 0.5, 0.75, and 1 inch deflections

Small Wire (17' Span)			
	Deflection		
	1 "	3/4 "	1/2 "
<b>Trial 1</b>	2.50 lbs	3.25 lbs	4.75 lbs
<b>Trial 2</b>	2.25 lbs	3.25 lbs	4.50 lbs
<b>Trial 3</b>	2.25 lbs	3.00 lbs	4.50 lbs
<b>Avg=</b>	<b>2.33 lbs</b>	<b>3.17 lbs</b>	<b>4.58 lbs</b>



**Figure 44:** Picture showing the relative height of the wire with respect to the furnace tube diameter

As seen in Figure 44, the wire is able to sag 75% of the furnace tube diameter. The furnace tubes that our re-designed let-off device will be using are 1" in diameter. This means that the wire will be able to deflect a maximum of  $\frac{3}{4}$ ". The objective for this test was met, indicated by Table #.

### **Section 3.22. 0.1020” Tension Window – Lower Bound**

The objective of this test is to obtain the minimum tension that will prevent the wire from touching the furnace tube when going through the annealing furnace. In order for the wire not to touch the furnace tube, a deflection of 0.75 inches must be the maximum deflection of the wire when the wire is experiencing the least amount of tension. For this test, two identical pieces of wood that are at least one inch in height will be obtained along with 17 feet of fully annealed 0.1020 inch diameter wire. One end of the wire should be fixed to one of the pieces of wood. The other end of the wire should be attached to a tension scale to obtain a reading of tension applied to the wire while traveling over the second piece of wood. In the center of the span a ruler should be present to read the maximum deflection of the wire. The wire will then be pulled to a deflection of 0.5 inches, 0.75 inches, and 1 inch while making sure the wire ends stay parallel to the ground. If the minimum tension is obtained, the test will have met the objective. If the minimum tension is not obtained, the test will not have met the objective. This test assumes that the set-up of the fully annealed wire will behave in the same fashion as it would inside a furnace tube while hot.

**Table 6:** Table showing the required tension to elevate the large diameter wire

<b>Large Wire (17' Span)</b>			
	<b>Deflection</b>		
	<b>1 "</b>	<b>3/4 "</b>	<b>1/2 "</b>
<b>Trial 1</b>	12.50 lbs	18.00 lbs	25+ lbs
<b>Trial 2</b>	13.50 lbs	17.25 lbs	25+ lbs
<b>Trial 3</b>	13.00 lbs	17.50 lbs	25+ lbs
<b>Avg=</b>	<b>13.00 lbs</b>	<b>17.58 lbs</b>	<b>25+ lbs</b>

Refer to Figure 44 for visual explanation of tension required for ¾” deflection. The objective for this test was met, indicated by Table #.

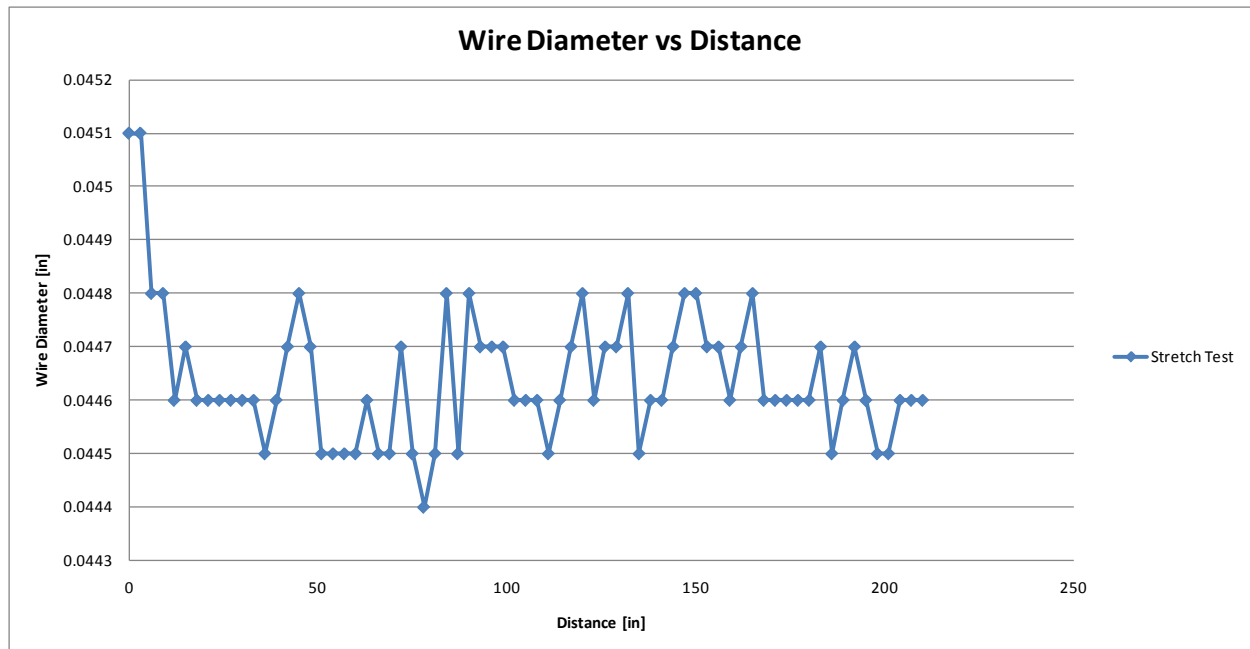
### **Section 3.23. 0.0453” Tension Window – Upper Bound**

The objective of this test is to ensure that the maximum tension calculated does not excessively deform the wire as it is traveling through the annealing furnace for the 0.0453 inch diameter wire. For this test, the re-designed let-off device will be set-up as if it will be running under normal conditions. The wire should be allowed to heat to temperature. The wire will then be pulled, after the furnace, with a tension scale to the maximum tension of 5.17 lbf, obtained from Section 4, *Conceptual Designs*, in the “ME 487-ME 488 Capstone Senior Design Project Report #1”. Then the wire will be cut before the furnace and the wire that was contained inside of the furnace will be removed. After letting the wire cool, the diameter of the wire will be measured every 3 inches through the entire span of wire that was in the furnace. If the maximum diameter variation, as compared to the maximum diameter recording of the incoming wire, is less than or equal to 0.001 inches the test will have met the objective. If the diameter variation is greater than 0.001 inches the test will not have met the objective.

**Table 7:** Table showing the wire diameter with respect to distance for the small diameter wire after the Tension Window – Upper Bound Test (Stretch Test)

<b>Distance (in)</b>	<b>0.0453 Stretch Test (in)</b>
0	0.0451
3	0.0451
6	0.0448
9	0.0448
12	0.0446
15	0.0447
18	0.0446
21	0.0446
24	0.0446
27	0.0446
30	0.0446
33	0.0446
36	0.0445
39	0.0446
42	0.0447
45	0.0448
48	0.0447
51	0.0445
54	0.0445
57	0.0445
60	0.0445
63	0.0446
66	0.0445
69	0.0445
72	0.0447
75	0.0445
78	0.0444
81	0.0445
84	0.0448
87	0.0445
90	0.0448
93	0.0447
96	0.0447
99	0.0447
102	0.0446
105	0.0446
108	0.0446

111	0.0445
114	0.0446
117	0.0447
120	0.0448
123	0.0446
126	0.0447
129	0.0447
132	0.0448
135	0.0445
138	0.0446
141	0.0446
144	0.0447
147	0.0448
150	0.0448
153	0.0447
156	0.0447
159	0.0446
162	0.0447
165	0.0448
168	0.0446
171	0.0446
174	0.0446
177	0.0446
180	0.0446
183	0.0447
186	0.0445
189	0.0446
192	0.0447
195	0.0446
198	0.0445
201	0.0445
204	0.0446
207	0.0446
210	0.0446



**Figure 45:** Graph showing the wire diameter vs distance for the small diameter wire for the stretch test

As it can be seen from Figure 45 the minimum diameter during this test is 0.444. This number is compared to the maximum diameter of the incoming wire, which can be found in Figure 41 to be 0.0452 inches. This gives a variation of 0.0008 inches. This variation is less than 0.001 inches therefore meets the objective of this test.

### **Section 3.24. 0.1020” Tension Window – Upper Bound**

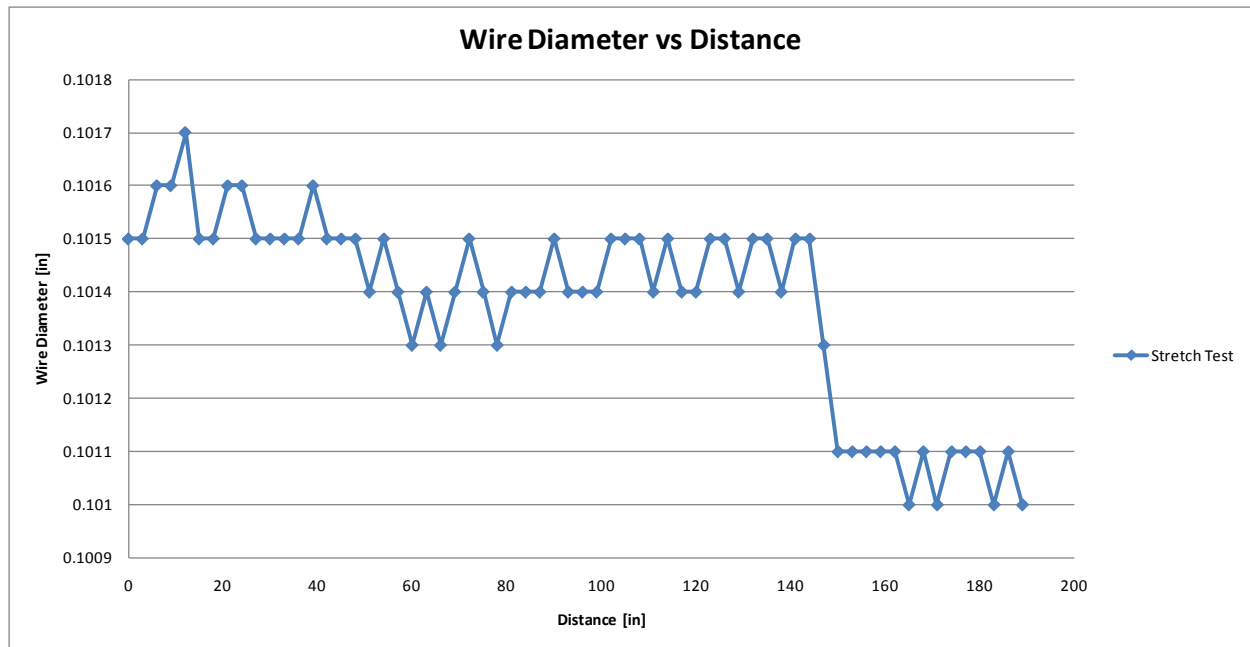
The objective of this test is to ensure that the maximum tension calculated does not excessively deform the wire as it is traveling through the annealing furnace for the 0.1020 inch diameter wire. For this test, the re-designed let-off device will be set-up as if it will be running under normal conditions. The wire should be allowed to heat to temperature. The wire will then be pulled, after the furnace, with a tension scale to the maximum tension of 26.23 lbf as defined in Section 4, *Conceptual Designs*, in the “ME 487-ME 488 Capstone Senior Design Project Report #1”. Then the wire will be cut before the furnace and the wire that was contained inside of the furnace will be removed. After letting the wire cool, the diameter of the wire will be measured every 3 inches through the entire span of wire that was in the furnace. If the maximum diameter variation, as compared to the maximum diameter recording of the incoming wire, is less than or equal to 0.001 inches the test will have met the objective. If the diameter variation is greater than 0.001 inches the test will not have met the objective.

**Table 8:** Table showing the wire diameter with respect to distance for the large diameter wire after the Tension Window – Upper Bound Test (Stretch Test)

<b>Distance (in)</b>	<b>.102 Stretch Test (in)</b>
0	0.1015
3	0.1015
6	0.1016
9	0.1016
12	0.1017
15	0.1015
18	0.1015
21	0.1016
24	0.1016
27	0.1015
30	0.1015
33	0.1015
36	0.1015
39	0.1016
42	0.1015
45	0.1015
48	0.1015
51	0.1014
54	0.1015
57	0.1014
60	0.1013
63	0.1014
66	0.1013
69	0.1014
72	0.1015
75	0.1014
78	0.1013
81	0.1014
84	0.1014
87	0.1014
90	0.1015
93	0.1014
96	0.1014
99	0.1014
102	0.1015
105	0.1015
108	0.1015



111	0.1014
114	0.1015
117	0.1014
120	0.1014
123	0.1015
126	0.1015
129	0.1014
132	0.1015
135	0.1015
138	0.1014
141	0.1015
144	0.1015
147	0.1013
150	0.1011
153	0.1011
156	0.1011
159	0.1011
162	0.1011
165	0.101
168	0.1011
171	0.101
174	0.1011
177	0.1011
180	0.1011
183	0.101
186	0.1011
189	0.101



**Figure 46:** Graph showing the wire diameter vs distance for the large diameter wire for the stretch test

As it can be seen from Figure 46 the minimum diameter during this test is 0.101 inches. This number is compared to the maximum diameter of the incoming wire, which can be found in Figure 43 to be 0.1022 inches. This gives a variation of 0.0012 inches. This variation is more than 0.001 inches therefore does not meet the objective of this test.

### **Section 3.25. Let-Off Device Ground Contact Width**

The objective of this test is to measure the width of the ground contact and verify that it is no greater than 28 inches. For this test, using a ruler/tape measure, the width of the base of the re-designed let-off device will be measured. The width of the device is defined as the side of the base that is perpendicular to the spool axis of rotation. If the width of the device is less than or equal to 28 inches the test will have met the objective. If the width of the device is more than 28 inches the test will not have met the objective. This test assumes that a width of 28 inches is acceptable because the previous device width is 28 inches.

Upon measuring the let-off device ground contact width, it was found to be exactly 28 inches. It can be seen that 28 inches is equal to the target of this test, therefore, this test meets the test objective.

### **Section 3.26. Let-Off Device Final Wire Height**

The objective of this test is to measure the height at the lowest setting of the re-designed let-off device and the highest setting and verify that it accommodates a final wire height of 36 inches to 60 inches. For this test a ruler/tape measure will be used to measure the distance from the ground to the final wire height when entering the furnace tube when the let-off device is on the

lowest height setting. Also, the height when the let-off device is on the highest setting should be measured and recorded. If the lowest number is less than or equal to 36 inches and the highest number is greater than or equal to 60 inches the test will have met the objective. If the lowest number is greater than 36 inches or the highest number is less than 60 inches the test will not have met the objective.

Upon measuring the let-off device final wire height, the minimum height was 34.375 inches and the maximum height was 60.25 inches. It can be seen that 34.375 inches is less than 36 inches and 60.25 inches is greater than 60 inches therefore this test's objective has been met.

### **Section 3.27. Let-Off Device Safety**

The objective of this test is to subjectively measure the safety of the re-designed let-off device as graded by a person that uses and is familiar with the current let-off device. For this test two device operators that normally work with the current let-off device will measure the safety of the re-designed let-off device. This subjective measurement should be based on pass/fail criteria. If the re-designed let-off device receives a pass grade, defined as the device being as safe as or safer than the current let-off device, the test will have met the objective. If the re-designed let-off device receives a fail grade, defined as the device not being as safe as or safer than the current let-off device, the test will not have met the objective. This test assumes that these operators can accurately compare the two let-off devices.

While talking to one of the people at Fort Wayne Metals that regularly operates several let-off devices, he said that the re-designed let-off device looked very safe. He also added that, in his opinion, the re-designed let-off device is as safe as or safer than the one currently in use. Because of his conclusion, the re-designed let-off device being as safe as or safer, this test's objective has been met.

### **Section 3.28. Let-Off Device Cosmetic Consistency**

The objective of this test is to subjectively measure the cosmetic consistency of the re-designed let-off device as compared to the rest of the plant décor. This test will also be graded by an established operator as a subjective pass or fail. For this test a technician that normally works with the current let-off device should subjectively measure the cosmetic consistency of the re-designed let-off device. If the re-designed let-off device receives a pass grade, defined as the device being as cosmetically consistent as the current let-off device, the test will have met the objective. If the re-designed let-off device receives a fail grade, defined as the device not being as cosmetically consistent as the current let-off device, the test will not have met the objective. This test assumes that these operators can accurately compare the two let-off devices.

While talking to one of the people at Fort Wayne Metals that regularly operates several let-off devices, he said that the re-designed let-off device looked very similar in appearance to the others, concerning the standard color of the let-off devices. He also added that, in his opinion, the re-designed let-off device is as cosmetically consistent as the ones currently in use. Because of his conclusion, this test's objective has been met.

## **Section 4 – Evaluation and Recommendations**

## **Section 4.1 System Validation**

This section will describe the evaluation and validation process of each system requirement. Requirements are associated to tests. These tests determine whether or not a requirement is validated, based on whether or not the test met the objective or not, along with the engineering judgment of the team. Evaluation of each requirement consists of evaluating the performance of the system based on each requirement and any recommendations that the team may have.

## **Section 4.2. Wire Diameter Tolerance**

The system requirement, “Wire Diameter Tolerance”, is attempted to be validated by two tests. These tests consist of “0.0453” Wire Diameter Variation” and “0.1020” Wire Diameter Variation”. Both of these tests met their respective test objectives. Because of this, the system requirement “Wire Diameter Tolerance” has been validated.

When comparing the current let-off device’s diameter variation to the re-designed let-off device’s diameter variation it seems that the re-designed let-off device’s diameter variation is larger. This does not necessarily mean that the re-designed let-off device did not make an improvement over the previous design. When looking at the diameter variation of the current let-off device, one must consider the quality of wire feeding into this let-off. The wire feeding into the current system had a tighter tolerance in diameter variation than the re-designed let-off and could have an impact on the diameter variation through the measured process.

The feeding current let-off diameter variation of the 0.1020” was approximately .0001 inch as can be seen in Figure 6-Capstone Senior Design Project Report #1. The feeding wire tolerance for the re-designed let-off was approximately 0.0002 inches in diameter. This is a 100% increase in the variation of the incoming wire, which could cause a significant increase in the wire diameter variation of the fully annealed wire process with our re-designed let-off. The feeding current let-off diameter variation of the 0.0453” was approximately .0001 inches as can be seen in Figure 6-Capstone Senior Design Project Report #1. The feeding wire tolerance for the re-designed let-off was approximately 0.0003 inches in diameter. This is a 200% increase in the variation of the incoming wire, which could cause a significant increase in the wire diameter variation of the fully annealed wire process with our re-designed let-off. There also could be other factors involved that we are unable to resolve at this point in time. Therefore it is to no advantage to compare the diameter variation between the current system and the re-designed system. However, the variation is still well within the acceptance criteria set for our system.

We are able to theoretically guarantee that the tension throughout the life of the spool is within our window during normal operation. The current let-off design does not account for the diameter change of the wire being pulled off the spool. As the wire gets closer to the core of the spool (torque arm getting shorter) the tension the wire is experiencing is increasing over the life of the spool if the resisting torque from the current magnetic brake does not change. This can be seen from Equation # shown below, which is a known and widely accepted method of calculating torque from force and distance measurements. The equation explains that in order to maintain the same amount of force (tension) as a distance decreases, resisting torque (braking torque) must decrease. The current design utilizes a constant braking torque from a magnetic

brake that is set at the beginning of the process and maintains the same position (braking torque) throughout the entire annealing process life of the spool, which increases tension as the spool empties.

$$\text{Torque} = \text{Force} * \text{Distance}$$

**Eq. 1**

The tension increase can cause more diameter variation than initially measured at the beginning of the process set-up. The operators measure the wire diameter at the beginning of the process when the resisting torque is initially set, and the spool is full, when the tension is at the process minimum. Any reduction in spool radius will produce a higher tension throughout the wire and possibly stretch the wire beyond the desired diameter tolerance and is most likely missed by production operators because of the lack of measurement at the end of the process.

### **Section 4.3. Wire Oscillation**

The system requirement, “Wire Oscillation”, is attempted to be validated by two tests. These tests consist of “0.0453” Wire Oscillation Amplitude” and “0.1020” Wire Oscillation Amplitude”. Only one of these tests met their respective test objectives. Because of this, the system requirement “Wire Oscillation” has not been validated by its respective tests directly.

The “0.1020” Wire Oscillation Amplitude” test met its objective while the “0.0453” Wire Oscillation Amplitude” did not. A second set of tests were performed to gather current oscillation data to compare to the re-designed let-off oscillation and determine if an improvement was made. The “0.0453” Wire Oscillation Amplitude” yielded oscillation amplitude of 0.4375 inches under normal running conditions while the “0.0453” Wire Oscillation Amplitude-Old Let-off Device” test yielded an amplitude of 0.75 inches which is an improvement of 42% over the current let-off device. It can also be noted that the “0.0453” Wire Oscillation Amplitude-Old Let-off Device” test was under ideal conditions and while running steady state. We know from previous observations that large snapping is a frequent occurrence which causes temporary large oscillations and tension fluctuations.

The “0.1020” Wire Oscillation Amplitude” yielded oscillation amplitude of 0.25 inches under normal running conditions while the “0.1020” Wire Oscillation Amplitude-Old Let-off Device” test yielded an amplitude of 0.375 inches which is an improvement of 33% over the current let-off device. It can also be noted that the “0.1020” Wire Oscillation Amplitude-Old Let-off Device” test was under ideal conditions and while running steady state. We know from previous observations that large snapping is a frequent occurrence which causes temporary large oscillations and tension fluctuations.

While our requirement is a maximum of 0.25 inch oscillation amplitude, in all likelihood the wire could oscillate more because of the deflection of the wire at normal running conditions as described in the tests (“0.0453” Tension Window – Lower Bound” and “0.1020” Tension Window – Lower Bound”) found in Section 3. We are able to conclude through our further testing that we were able to make a vast improvement in the wire oscillation of both wire sizes. Because of these two observations, the team is comfortable with the design despite the failure of the test objective. The team would also like to recommend that Fort Wayne Metals consider

installing larger tubes into the annealing furnace. This size increase would allow for more oscillation and not allow the wire to contact the inner surface of the tube causing pitting, cracking, and other possible surface defects. Also, this size increase would allow a lower minimum tension required to suspend the wire within the furnace tube. This minimum tension will be covered further in the report.

#### **Section 4.4. Wire Feed Rate**

The system requirement, “Wire Feed Rate”, is attempted to be validated by two tests. These tests consist of “0.0453” Wire Diameter Variation” and “0.1020” Wire Diameter Variation”. Both of these tests met their respective test objectives. Because of this, the system requirement “Wire Feed Rate” has been validated by its respective tests. The smaller wire is fully annealed at 30 feet per minute and the large wire is fully annealed at 4 feet per minute. Because these two wire sizes were able to run through the re-designed let-off device without problems confirms that the re-designed let-off device is able to accommodate the required wire velocities of the requirement.

#### **Section 4.5. Wire Diameter**

The system requirement, “Wire Diameter”, is attempted to be validated by two tests. These tests consist of “0.0453” Wire Diameter Variation” and “0.1020” Wire Diameter Variation”. Both of these tests met their respective test objectives. Because of this, the system requirement “Wire Diameter” has been validated by its respective tests. The smaller wire is fully annealed at a size of 0.0453” and the large wire is fully annealed at a size of 0.1020”. Because these two wire sizes were able to run through the re-designed let-off device without problems confirms that the re-designed let-off device is able to accommodate the required wire diameters of the requirement.

#### **Section 4.6. Wire Material**

The system requirement, “Wire Material”, is attempted to be validated by two tests. These tests consist of “0.0453” Wire Diameter Variation” and “0.1020” Wire Diameter Variation”. Both of these tests met their respective test objectives. Because of this, the system requirement “Wire Material” has been validated by its respective tests. Both sizes of wire are 304V Stainless. Because these two wire sizes were able to run through the re-designed let-off device without problems confirms that the re-designed let-off device is able to accommodate the required wire material of the requirement.

#### **Section 4.7. Wire Tension**

The system requirement, “Wire Tension”, is attempted to be validated by four tests. These tests consist of “0.0453” Tension Window-Lower Bound”, “0.1020” Tension Window-Lower Bound”, “0.0453” Tension Window-Upper Bound”, and “0.1020” Tension Window-Upper Bound”. Three of these tests met their respective test objectives and one of the tests did not meet its respective objective. Because of this, the system requirement “Wire Tension” has not been validated.

All of the tests met their respective objective except the “0.1020” Tension Window-Upper Bound”. The objective of this test was to ensure that the maximum tension calculated did not deform the wire more than 0.001” as it was traveling through the annealing furnace. The deformation of the wire upon subjecting the wire to 26.23 lbf was 0.0012 inches. This is slightly above the acceptable deformation of the wire under the high tension. This indicates that the theoretical calculations were not 100% correct in calculating the upper bound for the 0.1020” diameter wire. This could be due to several reasons, including the wire not being exactly 0.1020” in diameter. Therefore the team recommends retesting the upper bound of the tension window, however it is felt that the deformation is not overly excessive and could still be close to the calculated range when taking into account the other uncontrolled variables.

#### **Section 4.8. Let-Off Ground Contact Width**

The system requirement, “Let-off Ground Contact Width”, is attempted to be validated by one test. This test is “Let-Off Device Ground Contact Width”. This test met its test objective. Because of this, the system requirement “Let-off Ground Contact Width” has been validated by the test.

#### **Section 4.9. Wire Height**

The system requirement, “Wire Height”, is attempted to be validated by one test. This test is “Let-Off Device Final Wire Height”. This test met its test objective. Because of this, the system requirement “Wire Height” has been validated by the test.

#### **Section 4.10. Device Safety**

The system requirement, “Device Safety”, is attempted to be validated by one test. This test is “Let-Off Device Safety”. This test met its test objective. Because of this, the system requirement “Device Safety” has been validated by the test.

The operator was also asked to evaluate the re-designed let-off for instances where improvements could be made to increase the ease of use of the machine. These recommendations include providing some sort of leverage to reduce the lifting force needed to lift the weight of the added components when raising the spool support to accommodate larger spool diameters. Another recommendation is the addition of hand adjustable bolts attached to the adjustable brake. It would make it easier for the operators to quickly adjust the initial resisting torque for the various wire sizes without tools. A final recommendation is an extension “stick” that would allow the operator to wrap the wire around the “snap-reducing cylinder” without having to lean down or walk around the machine.

#### **Section 4.11. Device Cosmetic Consistency**

The system requirement, “Device Cosmetic Consistency”, is attempted to be validated by one test. This test is “Let-Off Device Cosmetic Consistency”. This test met its test objective. Because of this, the system requirement “Device Cosmetic Consistency” has been validated by the test.



#### **Section 4.12. Final Cost**

The final cost for our prototype is represented in the table below:

**Table 9:** Final Cost of Prototype Table

<b>Parts Ordered</b>			
<b>Requisition Description</b>	<b>Date</b>	<b>Price (\$)</b>	<b>Order Description</b>
Jeff Wilder - Payoff	27-Jan-10	498.09	Magnetic Brake
Jeff Wilder Prototype parts	4-Feb-10	4,220.00	Machined parts from original let-off
Jeff Wilder-Payoff Sheet Metal	4-Feb-10	151.85	Sheet Metal for hinged cover
JEFF WILDER PROJECT	4-Feb-10	25.42	Misc. Parts
JEFF WILDER PROJECT	5-Feb-10	32.13	Misc. Parts
JEFF WILDER PROJECT	22-Feb-10	435.31	Misc. Parts
JEFF WILDER PROJECT	15-Mar-10	1,265.00	Roller Straightener
JEFF WILDER PROJECT	15-Mar-10	21.79	Misc. Parts
JEFF WILDER PROJECT	22-Mar-10	38.19	Misc. Parts
		<b>Total Price</b>	
		6,189.69	

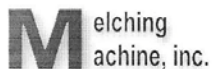
As the above table shows, our final cost is less than half of the \$15,000 budget allocated by Fort Wayne Metals for our project.

## **Conclusion**

During this second semester of senior design we have successfully built and tested the conceptual design which was detailed during our first semester of senior design. Through our building process we found that we had to redesign some of the components of our prototype in order to meet the real world operational demands that it needed to accommodate. Three of our major component changes were the readjustment of our gearing ratio after getting hands on experience with the adjustable braking system, redesigning our snap-reducing cylinder with lips to prevent wire with heavy cast from sliding off of the cylinder during operation, and reorienting our roller straightener in order to prevent the wire from slipping because of the sharp angle of entry. After finalizing our prototype we tested it with mixed results. Most of our tests met our expectations although a few did not meet the requirements that we had set forth. Overall our redesigned let-off has shown significant improvements in wire oscillation, with a 33-42% reduction, and diameter variation parameters when compared to the original Fort Wayne Metals wire let-off. With these results in mind, we feel that our prototype could eventually meet all requirements if given more time to redesign our conceptual design using the iterative engineering design process. With more evaluation based on the recommendations outlined in this report we believe that our prototype could be a much welcomed addition to the Fort Wayne Metals campus.

## **Appendix**

**Original Let-Off Parts**  
From Melching Machine, inc.



1630 Baker Drive Phone (260) 622-4315  
Ossian, IN 46777 Fax (260) 622-4361

**Our Quotation #009868-00**

01/20/2010

To :

FORT WAYNE METALS RESEARCH PRO  
9609 ARDMORE AVENUE  
FORT WAYNE IN 46809

Terms : NET 30

Attention : BRAD SORDELET

*We are pleased to quote your requirements as shown below.*

Item	Part / Rev / Description / Details	Quantity Quoted	Unit Price	Extended Price
001	FWM-RIPO DRWGS. SERIES U/M LOT FWM-RIPO-102 THRU FWM-RIPO-140 (QUANTITIES PER YOUR QUOTE REQUEST PT.1)  Delivery: 2 WEEKS FROM DATE OF PURCHASE ORDER	1.000	4,220.00000	\$ 4,220.00

Thank you for your interest in our company as one of your suppliers.

PLEASE NOTE:

Parts will be produced and shipped at the quoted lead-times and the above stated prices will be in effect. Parts so released and produced on an individual basis will have a 20% adder, added to the price. This is due to additional machining required.

If customer makes changes to a job that are different than what was originally quoted, Melching Machine reserves the right to charge additional prices to reflect those changes.

With best regards,

MF1006 08/29/05

A handwritten signature in cursive script, appearing to read 'Gordon Skux', is written over a horizontal line.

Customer

Page # 1

A handwritten signature in cursive script, appearing to read 'Gordon Skux', is written over a horizontal line.

Authorized Signature

**Magnetic Brake**  
Magnetic Technologies LTD  
Part Number: 839-016  
Price: \$498.09

**Roller Straightener (Unknown Company- Used by Fort Wayne Metals)**  
Price: \$1265.00

**McMaster-Carr order for Big Break Down Constant Tension Let-Off**  
Part number: 8497K651  
Number of Parts: 1  
Price: \$257.74 per foot (1 foot needed)

The screenshot shows the McMaster-Carr website in a Windows Internet Explorer browser. The page displays the product details for item 8497K651, an Acetal Copolymer Rod. The product is described as being in stock at \$257.74 per foot. The page includes a 'Product Detail' section on the left with a description and an 'ADD TO ORDER' button. The main content area shows a 3D model of the rod and a detailed specification table. The bottom of the page features a navigation bar with links to Home, Help, Privacy Policy, Returns, Security Settings, Home Page Settings, Terms of Sale, Terms of Use, Careers, and Bookmarks.

**Product Detail**

8497K651  
(Same as 8497K65)

Acetal Copolymer Rod 8"  
Diameter, White

**In stock** at \$257.74 per Ft.

This product is sold in  
Lengths of 1 Ft.

Ft.

**ADD TO ORDER**

[Bookmark this Product](#)  
[Catalog Page](#)  
[Product Specifications](#)  
[More About Performance](#)  
[Plastics](#)  
[Current Order - 0 lines](#)

**Plastics**  
This product matches all of your selections.

Part Number: 8497K651

**Material** Acetal

**Acetal Material** Acetal Copolymer

**Backing** Plain Back

**Finish** Smooth

**Shape** Rods and Discs

**Rods and Discs Type** Rod

**Length** 12"

**Diameter** 8"

**Diameter Tolerance** +.3"

**Opaque** White

**Operating Temperature Range** -40° to +180° F

**Softening Point** Not Rated

**Performance Characteristic** Wash-Down Applications

**Tensile Strength** Good

**Impact Strength** Good

**Tolerance** Standard

**Hardness** Rockwell M78-M88

**Specifications Met** American Society for Testing and Materials (ASTM), Food and Drug Administration (FDA) Compliant, National Sanitation Foundation (NSF) Compliant

**ASTM Specification** ASTM D6100

Home | Help | Privacy Policy | Returns | Security Settings | Home Page Settings | Terms of Sale | Terms of Use | Careers | Bookmarks

Part number: 2431K73 for 1" shaft diameter  
Number of Parts: 1  
Price: \$63.63 each

McMaster-Carr - Item 2431K73 - Windows Internet Explorer

http://www.mcmaster.com/#2431k73/=5uvut9

File Edit View Favorites Tools Help

McMaster-Carr - Item 2431K73

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2431K73 **FIND** CONTACT US BOOKMARKS ORDER HISTORY BUILD ORDER

Need help finding a product?  
E-mail or call (630) 600-3600.

02/17/10 - 0 lines

Product Detail

2431K73

Stamped-SS Flange-Mounted Ball Bearing-ABEC-1 2 Bolt, for 1" Shaft Diameter

In stock at \$63.63 Each

☐ Each

ADD TO ORDER

Bookmark this Product

Catalog Page

Product Specifications

3-D Model

Technical Drawing

Current Order - 0 lines

Download Print How Can We Improve?

Mounted Bearings

This product matches all of your selections.

Part Number: 2431K73 \$63.63 Each

Mounting Style Flange Mount

Flange Mount Type Standard

Type General Purpose

Bearing Style Ball

For Shaft Diameter 1"

Dynamic Radial Load Capacity, lbs. 891

Maximum rpm 3,000

ABEC Precision Bearing Rating ABEC-1

Housing Material Stainless Steel

Stainless Steel Housing Material Stamped Type 304 Stainless Steel

Bearing Material Steel

Bearing Insert Material Type 440C Stainless Steel

Ball Bearing Material Type 440C Stainless Steel

Temperature Range -10° to +220° F

Bearing Construction Single-Sealed

Maximum Shaft Misalignment 3°

Secures/Attaches With Double Set Screw

Note Bearing insert is deep grooved and has rubber seals that retain lubricant and block out dirt. Set screws included.

Home | Help | Privacy Policy | Returns | Security Settings | Home Page Settings | Terms of Sale | Terms of Use | Careers | Bookmarks

Done

Internet 100%

Part number: 4768K7 for 1" shaft diameter  
Number of Parts: 2  
Price: \$30.44 each

McMaster-Carr - Item 2431K73 - Windows Internet Explorer

http://www.mcmaster.com/#2431k73/=Sumut9

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McMaster-Carr - Item 2431K73

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4768K7 **FIND** CONTACT US BOOKMARKS ORDER HISTORY BUILD ORDER

**Product Detail**

4768K7

Hi-Speed/Hi-Load Slt Ball Brng W/Shaft Collar for 1" Shaft Dia, 2" OD with Retaining Ring

In stock at \$30.44 Each

☐ Each

ADD TO ORDER

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Catalog Page  
Product Specifications  
Current Order - 0 lines

**Ball and Roller Bearings**

This product matches all of your selections.

Part Number: 4768K7 \$30.44 Each

Type Ball Bearings

Ball Bearing Style Double Sealed with Retaining Ring and Extended Inner Ring

Ball Bearing Type General Purpose

System of Measurement Inch

For Shaft Diameter 1"

Outside Diameter 2"

Width 5/8"

ABEC Precision Bearing Rating Not Rated

Bearing Trade Number 7616

Dynamic Radial Load Capacity, lbs. 2,970

Dynamic Radial Load Capacity Range, lbs. 1,501 to 3,000 lbs.

Maximum rpm 6,000

Maximum rpm Range 3,001 to 7,500

Temperature Range -20° to +250° F

Bearing Material Steel

Seal Material Synthetic Rubber

Specifications Met Not Rated

Note Includes two set screws.

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Part number: 6245K832 for 5/8" bore diameter and B-section V-belt  
Number of Parts: 1  
Price: \$7.46 each

McMaster-Carr - Item 2431K73 - Windows Internet Explorer

http://www.mcmaster.com/#2431k73/=5uuut9

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McMaster-Carr - Item 2431K73

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6245K832 [FIND](#) [CONTACT US](#) [BOOKMARKS](#) [ORDER HISTORY](#) [BUILD ORDER](#)

**Product Detail**

6245K832  
(Same as 6245K83)

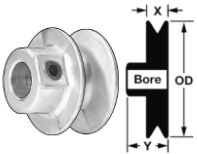
Die Cast V-Belt Pulley 5L,  
B-Section, 2-1/2" OD, 5/8"  
Bore

In stock at \$7.46 Each

☐ Each  
[ADD TO ORDER](#)

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**Pulleys for Belts**  
This product matches all of your selections.



Part Number: 6245K832 \$7.46 Each

Pulley Type	Drive Pulleys
For Belt Type	V-Belt Pulleys
Pulley Design	Solid
Number of Grooves	1
System of Measurement	Inch
V-Belt Section and End Dimensions (Top Width x Height)	5L-Section - 2 1/32" x 3/8", B-Section - 2 1/32" x 13/32", BX-Section - 2 1/32" x 13/32"
Outside Diameter	2-1/2"
Bore Type	Finished Bore
Finished Bore Pulley Style	Standard
Bore Size (ID)	5/8"
X-Dimension	3/4"
Y-Dimension	1-1/4"
V-Dimension (Pitch Dia.)	2"
Keyway Size	3/16" Wd. x 3/32" Dp.
Pulley Material	Zinc Die Cast
Specifications Met	Not Rated
Note	Includes a standard keyway and set screw.

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Part number: 6204K422 for 1" bore diameter and B-section V-belt  
Number of Parts: 1  
Price: \$45.60 each

McMaster-Carr - Item 2431K73 - Windows Internet Explorer

http://www.mcmaster.com/#2431k73/=Sunut9

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McMaster-Carr - Item 2431K73

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02/17/10 - 0 lines

6204K422 [FIND](#) [CONTACT US](#) [BOOKMARKS](#) [ORDER HISTORY](#) [BUILD ORDER](#)

**Product Detail**

6204K422  
(Same as 6204K42)

Cast Iron V-Belt Pulley  
9.75" OD, 1" Bore

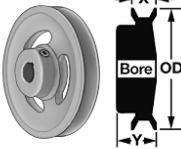
In stock at \$45.60 Each

☐ Each  
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**Pulleys for Belts**  
This product matches all of your selections.

Part Number: 6204K422 \$45.60 Each



Pulley Type Drive Pulleys  
For Belt Type V-Belt Pulleys  
Pulley Design Spoked  
Number of Grooves 1  
System of Measurement Inch  
V-Belt Section and End Dimensions (Top Width x Height) 4L-Section - 1/2" x 5/16", 5L-Section - 21/32" x 3/8", A-Section - 1/2" x 5/16", AX-Section - 1/2" x 5/16", B-Section - 21/32" x 13/32", BX-Section - 21/32" x 13/32"  
Outside Diameter 9-3/4"  
Bore Type Finished Bore  
Finished Bore Pulley Style Standard  
Bore Size (ID) 1"  
X-Dimension 7/8"  
Y-Dimension 1-17/32"  
A Belts Pitch Dia. 9"  
B Belts Pitch Dia. 9.4"  
Keyway Size 1/4" Wd. x 1/8" Dp.  
Pulley Material Cast Iron  
Specifications Met Not Rated  
Note Includes a standard keyway and set screw.

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Part #: 6204K291

Quantity: (1)

V-belt pulley, B-section

Price: \$21.79 each

McMaster-Carr - V-Belt Pulleys - Windows Internet Explorer

http://www.mcmaster.com/#v-belt-pulleys/=66cplw

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McMaster-Carr - V-Belt Pulleys

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E-mail or call (830) 600-3600.

03/11/10 - 0 lines

v-belt pulley **FIND** CONTACT US BOOKMARKS ORDER HISTORY BUILD ORDER

**Product Detail**

6204K291  
(Same as 6204K29)  
Cast Iron V-Belt Pulley  
5.45" OD, 5/8" Bore  
In stock at \$21.79 Each

☐ Each  
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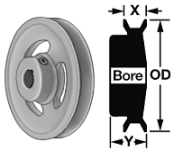
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Catalog Page  
Product Specifications  
Current Order - 0 lines

PRINT HOW CAN WE IMPROVE?

Bore Type > Finished Bore Pulley Style > Bore Size (D) > V-Belt Section and End Dimensions (Top Width x Height) > Outside Diameter

**Pulleys for Belts**  
This product matches all of your selections.

Part Number: 6204K291 \$21.79 Each



Pulley Type	Drive Pulleys
For Belt Type	V-Belt Pulleys
Pulley Design	Spoked
Number of Grooves	1
System of Measurement	Inch
V-Belt Section and End Dimensions (Top Width x Height)	B-Section - 2 1/32" x 13/32"
Outside Diameter	5.45"
Bore Type	Finished Bore
Finished Bore Pulley Style	Standard
Bore Size (ID)	5/8"
X-Dimension	7/8"
Y-Dimension	1-5/16"
A Belts Pitch Dia.	4.7"
B Belts Pitch Dia.	5.1"
Keyway Size	3/16" Wd. x 3/32" Dp.
Pulley Material	Cast Iron
Specifications Met	Not Rated
Note	Includes a standard keyway and set screw.

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B-section V-belt (adjustable twist lock)

Part Number: 6173K38

Price: \$8.75 per foot

Quantity:(8) feet needed

McMaster-Carr - V Belts - Windows Internet Explorer

http://www.mcmaster.com/#v-belts/=626i4g

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McMaster-Carr - V-Belts

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belt **FIND** CONTACT US BOOKMARKS ORDER HISTORY BUILD ORDER

**Product Detail**

6173K38

Twist Lock Adjustable-  
Length V-Belting 5L, B, Belt  
Type, 5/8" Belt Width

**In stock** at \$8.75 per Ft.

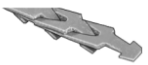
☐ Ft.

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**Belts**

This product matches all of your selections.

 **Part Number: 6173K38** **\$8.75 per Ft.**

Form	Belting
Type	V-Belts
V-Belt Type	Adjustable-Length
Adjustable-Length V-Belt Type	Twist Lock
Material	Urethane
Urethane Type	Polyurethane
Material Detail	Made of a polyurethane elastomer reinforced with multiple plies of polyester fabric.
Belting Length	Cut-to-Order
V-Belt Section	B
Top Width	5/8"
Height	19/32"
<b>Links per Foot</b>	<b>13</b>
Color	Red
Specifications Met	Not Rated
Instructions	Simply twist to couple or uncouple this belting.

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Part #: 6205K142  
Description: V-belt pulley with adjustable pitch diameter  
Quantity: 1  
Price: \$32.47

McMaster-Carr

OVER 460,000 PRODUCTS

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v belt pulley

CONTACT US

BOOKMARKS

ORDER HISTORY

BUILD ORDER

Product Detail

6205K142  
(Same as 6209K55)  
Cast Iron Variable-Pitch  
V-Belt Pulley 4.75" OD, 5/8"  
Bore, Single Groove  
In stock at \$32.47 Each

Each

ADD TO ORDER

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Catalog Page

Product Specifications

Current Order - 0 items

PRINT

HOW CAN WE IMPROVE?

Bore Type - Finished Bore Pulley Style - Bore Size (OD) - B Belts Pitch Dia

Pulleys for Belts

This product matches all of your selections.

Part Number: 6205K142

\$32.47 Each

Pulley Type	Drive Pulleys
For Belt Type	V-Belt Pulleys
Pulley Design	Cast
Number of Grooves	1
System of Measurement	Inch
V-Belt Section and End Dimensions (Top Width x Height)	3L Section - 3/8" x 7/32", A-Section - 1/2" x 5/16", AX-Section - 1/2" x 5/16", B-Section - 21/32" x 13/32", BX-Section - 21/32" x 13/32"
Outside Diameter	4-3/4"
Bore Type	Finished Bore
Finished Bore Pulley Style	Variable Pitch
Bore Size (OD)	5/8"
X-Dimension	11/16"-1-1/16"
V-Dimension	1-15/16"
3L Belts Pitch Dia.	3.3"-4.1"
A Belts Pitch Dia.	3.4"-4.4"
B Belts Pitch Dia.	3.7"-4.7"
Keyway Size	3/16" Wd. x 3/32" Dp.
Pulley Material	Cast Iron
Specifications Met	Not Rated

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Done

Part #: 91175A644

Description: M6 socket head cap screw thumb heads

Quantity: 1 package

Price: \$5.72 per package of 25

McMaster-Carr - Thumb Screws - Mozilla Firefox

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http://www.mcmaster.com/#thumb-screws/=40K99

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03/18/10 - 0 Items

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Product Detail

91175A644  
(Same as 91175A064)

Metric Press-Fit Plastic  
Thumb Screw Head  
Knurled, Yellow, Fits M6  
Screw, 16mm A, 7.6mm B  
In stock at \$5.72 per Pack

This product is sold in  
Packs of 25

☐ Packs of 25  
ADD TO ORDER


Bookmark this Product  
Catalog Page  
Product Specifications  
Current Order - 0 Items

PRINT HOW CAN WE IMPROVE?

Screws > Head Type > Knob Type > Fits Socket Head Cap Screw Size > Head Width (Wd.) > Compare Items

Thumb Screws  
This product matches all of your selections.

Part Number: 91175A644



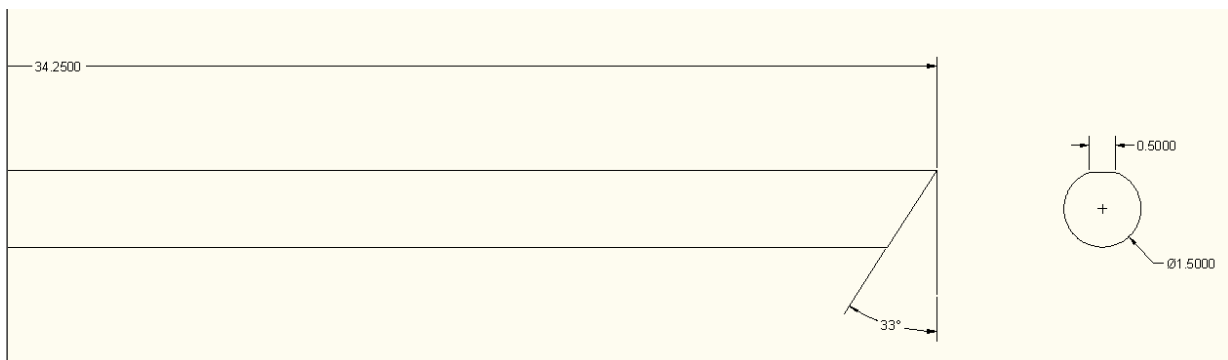
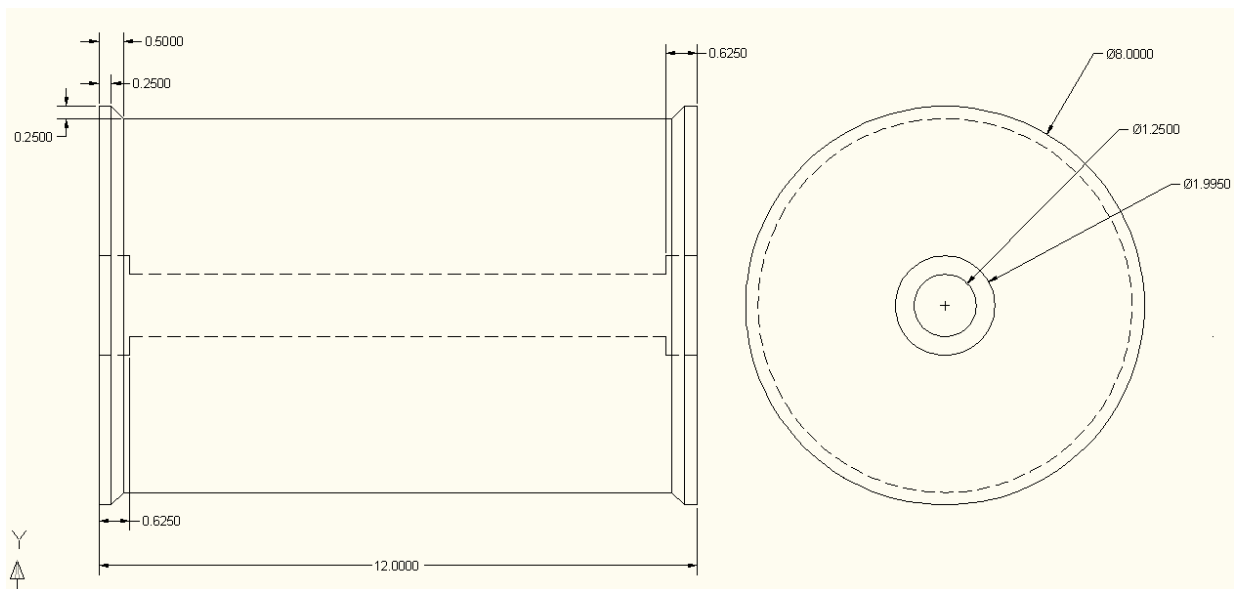
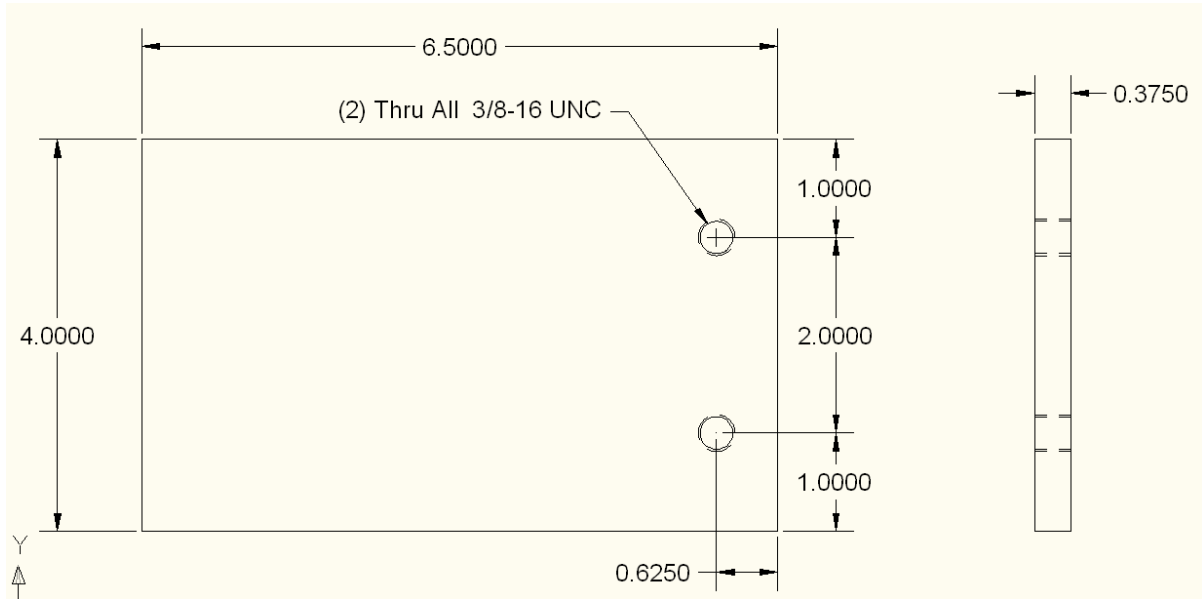
Plastic Type Acetal  
Head Type Thumb Screw Heads  
Material Type Plastic  
Finish Plain  
Fits Socket Head Cap Screw Size M6  
Knob Type Knurled  
Head Width (Wd.) 16 mm  
Head Height (Ht.) 7.6 mm  
Color Yellow  
Head Temperature Range 32° to 180° F  
Specifications Met Not Rated  
Thumb Screw Quantity Individual Thumb Screw

\$5.72 per Pack of 25

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Done

## CAD Drawings



## Project Gantt Chart

